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ABSTRACT

This master's thesis describes the development of an expert system and interactive videodisc computer-based instructional job aid used for assisting in the integration of electron beam lithography devices. Comparable to all comprehensive training, expert system and job aid development require a criterion-referenced systems approach treatment to ensure training validity and reliability. The expert system and job aid were designed by Grumman Simulation/Trainer Products to be delivered via computer-assisted instruction at the Grumman Great River Operations (GRO). This project utilized the Instructional Systems Development methodology for the training development of electron beam lithography procedures. Each phase of this model is described, including analysis, design, development, implementation, and evaluation. Additionally, design factors inherent to all computer-based training applications are presented. Appendices contain a needs analysis; a job analysis; project planning; examples of job aid storyboarding; the expert system flow chart, decision tree, matrix, and screen design; examples of lesson codes; a course aid; a discrepancy report; a reaction survey; formative evaluation discrepancy reports; reaction survey analysis results; data analysis specification; and summative evaluation discrepancy reports. (26 references) (DB)

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THE SCHOOL OF MEDIA AND ARTS

of

NEW YORK INSTITUTE OF TECHNOLOGY

announces the

Final Examination

of

Kimberly Stevenson

for the degree of

MASTER OF SCIENCE

in

TRAINING AND LEARNING TECHNOLOGY

A Computer-Based, Interactive Videodisc Job Aid and Expert System for Electron Beam Lithography Integration and Diagnostic Procedures

Abstract

Not all training requirements include comprehensive criterion-referenced instruction. After careful analysis, it is often determined that reference to job-related tasks or job performance aids are more appropriate for solving performance deficiencies. This paper describes the development of an expert system and interactive videodisc computer-based job aid used for assisting the integration of electron beam lithography devices. Comparable to all comprehensive training, expert system and job aid development require a criterion-referenced systems approach treatment to ensure training validity and reliability. Each phase of the Instructional System Development model is described, including analysis, design, development, implementation, and evaluation. In addition, design factors inherent to all computer-based training applications are presented.

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A COMPUTER-BASED, INTERACTIVE VIDEODISC JOB AID AND EXPERT SYSTEM FOR ELECTRON BEAM LITHOGRAPHY INTEGRATION AND DIAGNOSTIC PROCEDURES

by

Kimberly Diane Stevenson

B.A. 1987, State University of New York, College at Geneseo

A Thesis/Project

submitted to The Faculty of the

School of Media and Arts

of The New York Institute of Technology in partial satisfaction
of the requirements for the degree of

Master of Science

May 1990

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CHAPTER 1

INTRODUCTION

Overview

There are some trainers who have trouble justifying a training program that produces a temporary change in behavior rather than facilitates permanent learning. However, there are training settings where a reference to job tasks and diagnostic procedures is more appropriate for meeting training needs and enhancing performance than comprehensive procedural training. This method of delivery is defined as the expert system and job aid. The project described in this document established that the expert system and job aid were required to meet defined training needs. This judgment was based on logical job performance variables and learner aptitude factors.

There is some suggestion that the expert system and job aid are not valid forms of training. This opinion is based on incorrect assumptions that a comprehensive analysis is not required and that there are limited ways of evaluating the expert system and job aid. Comparable to all comprehensive training, the expert system and job aid require a criterion-referenced, systems approach treatment to ensure training validity and reliability.

The training setting illustrated in this project was Electron Beam Lithography Systems Integration, Grumman Great River Operations (GRO). The expert system and job aid were designed by Grumman Simulation/Trainer Products (S/TP) to be delivered via computer-assisted instruction. This project

utilized the instructional systems development (ISD) methodology for the training development of electron beam lithography procedures. Due to the sensitivity of these procedures, some information has been omitted from this document. Also, the design and perceptual issues common to all computer-based training applications were exercised. Finally, the evaluation of the expert system and job aid were implemented to verify training effectiveness and efficiency.

Background

The Electron Beam Lithography devices were designed by International Business Machines (IBM). Integration of the e-beam lithography systems was performed by Grumman GRO. The e-beam lithography technology used an electron beam imaging technique to write information onto computer chips. The current generation of the electron beam system at the time of this writing, the EL-3+, became operational in the early 1980s. The EL-3+ greatly improved wafer writing time, increased data per chip, and decreased chip and wafer size through more automated procedures. This technique deleted the time-consuming masking step based on its direct write capability. In comparison to optical writing techniques of the past, electron beam projection was advantageous in that it wrote more precise measures and correct pattern positions on wafers.

Grumman Simulation/Trainer Products was approached by IBM and Grumman GRO with a list of e-beam lithography tasks to be trained. Because the e-beam lithography device was integrated and maintained by Grumman and operated by IBM, both companies

agreed that a return on training investment would benefit both organizational needs. It was originally determined that the initial training setting would be Grumman GRO, where the prototype EL-3+ systems were being integrated and tested. After the training was evaluated and approved by Grumman GRO, it would be delivered on-site to IBM, Fishkill operations.

It was agreed by IBM, Grumman GRO, and Grumman S/TP that due to the large number of e-beam lithography procedures, a portion of the original task list would be implemented as a prototype training project. Prototyping an interactive multi-media application can be a time and money-saving investment. In concept, prototyping is testing a working model of a small portion of the total program to assure that the concept is sound and workable (Bruce, 1990). If the preliminary training product was approved by Grumman GRO and IBM, all procedures would then be trained. The specific task delegated to be trained was defined as the "beam bring up."

Systems integration procedures on the Electron Beam Lithography device were performed by a limited number of engineers. The engineers were taught via informal on-the-job training (OJT). It was believed that a formal training program would positively effect the performance of systems engineers.

Statement of the Problem

A major concern identified by e-beam management and engineers was the increased role specialization of the EL-3+ integration team. If integration procedures beyond the present engineers' knowledge needed to be performed, specialized

engineers had to be pulled from other responsibilities. This was particularly a problem concerning diagnostic procedures. Few engineers had the ability to discriminate between diagnostic conditions or the problem solving knowledge required for the appropriate corrective actions. Therefore, troubleshooting procedures could only be performed by a few select engineers. If these key personnel were unavailable, device downtime resulted. This reduced the time available for productive EL-3+ integration and resulted in schedule and budget repercussions.

A second concern identified the lack of standardized procedures being trained and documented as a result of informal OJT. Because different engineers had various approaches, the trainees learned different procedures based on who was doing the training. In addition, OJT was communicated verbally. This hindered written documentation of standardized procedures and provided no reference for correct e-beam lithography procedures. More importantly, there was concern that as qualified engineers left the company and took their knowledge with them there would be a lack of e-beam lithography intelligence.

Purpose of the Project

The ultimate purpose of the project was to develop a job aid to guide qualified system engineers in the integration of the EL-3+ device. In addition, an expert system was designed to enhance the job aid. The expert system would assist engineers in the interpretation of astigmatism conditions and diagnosis of corrective actions. This would improve the performance of critical astigmatism tasks in the beam bring up process, and

decrease the specialized knowledge of troubleshooting procedures among engineers. This would increase wafer write quality, decrease device downtime, and increase productivity.

Other important objectives were to stabilize the future of the Electron Beam Lithography program, and secure the positions of the Grumman GRO, and S/TP ISD in e-beam lithography technology. These goals were met through several training end results. First, because no e-beam lithography procedures had been recorded, the task analysis would serve as the only existing, accurate documentation. As a result, the expert system and job aid would provide the engineers with standardized e-beam lithography procedures, accurate device configurations, and a principle specification for future device upgrades. This documentation would guarantee that knowledge of e-beam lithography procedures would not be lost as qualified engineers left the company.

Because standardized e-beam lithography procedures would be available to all engineers, there would be a decrease in engineering specialization. This would improve the engineers' versatility to deal independently with e-beam lithography tasks and problems. As a result, other qualified engineers would be free from OJT duties and more available for actual integration procedures. This would improve the productivity of the e-beam lithography program.

The final purpose of this project was to enhance the EL-3+ as a marketable product. As IBM investigated other chip writing lithography technologies and explored abandoning electron beam

lithography, there were concerns of how to "sell" the technology. It was agreed that support training would improve the salability of e-beam lithography technology. This would create a profit for IBM and increase the probability that Grumman GRO would continue to integrate e-beam lithography devices.

Definition of Terms

Algorithm- Specific steps taken in determining an exact solution to a problem.

CAI- Computer Aided Instruction- Instruction that refers directly to the computer as the media used for instructional delivery.

CBT- Computer-Based Training- An umbrella term which includes (CAI), Computer Managed Instruction (CMI), and Computer Supported Learning Resource (CSLR) activities.

Domain Expert- A subject matter expert in a specific domain of knowledge, who provides technical support during knowledge engineering and expert system development.

Expert System- Computer-based tool that emulates the performance of an expert in a specific domain of knowledge.

Heuristics- Rules of thumb, developed through experience, that facilitate the solution to a problem.

IVD- Interactive Video Disc- A laser disc medium that presents visual and audio information through the use of a computer.

Knowledge Engineer- A training designer who specializes in the development of expert systems. Main task is to elicit important information from domain experts and code that knowledge in a form the expert system can use.

SME- Subject Matter Expert- A person considered an expert in a specific field of knowledge who provides technical support during training development.

Assumptions

1. That systems engineers will use the CAI expert system and job aid training for e-beam lithography procedure reference, rather than rely on OJT training or guidance from other systems engineers.
2. That systems engineers have baseline knowledge of e-beam concepts, discriminations, and theory.

Limitations

1. That Electron Beam technology was relatively new and the analysis was derived from a first time, prototype system. As a result, the tasks were relatively dynamic and subject to modification as the technology matured. This occurred during training development and after training delivery.
2. That the target population was defined as EL-3+ systems engineers. It was assumed that this target population had some experience with operating existing EL-3 devices, had a baseline knowledge of electron beam lithography theory, and some formal physical science education. A population that does not fit the learner analysis profile would be inappropriate as end users, and would nullify training validity and reliability.
3. That the training was developed specifically to meet the needs of Grumman GRO and IBM organizations. The training is

in the English language, and reflects the culture of the United States, in the last decade of the 20th century. Therefore, the training would be inappropriate for use in another type of organization, culture, country, or time period other than those mentioned above.

Method and Procedures

The instructional systems development model used for EL-3+ training represented a systematic approach to training development. This approach focused on producing a training product via an iterative process. During this process, each phase accepted and utilized information from the previous phase and produced an output that was used at the next phase of the system. This process resulted in training efficiency and effectiveness. There were five major phases included in the instructional systems approach. They were the analysis, design, development, implementation, and evaluation phases.

Analysis

The analysis phase was important because it was the foundation for succeeding e-beam lithography design and development phases, and the instructional system as a whole. During this phase, job information was collected to help focus training needs and desired outcomes. The process began with the identification of a terminal instructional goal that precisely described desired outcomes of e-beam lithography training. Based on the terminal instructional goal, a needs assessment was conducted to support the validity for the training. The needs assessment verified what job duties would and would not be

selected for training. From these selected duties, a task analysis was performed to define the specific tasks necessary for successful performance of the terminal goal. This determination was based on interviews and observations at job sites, with confirmation from SME's (Subject Matter Experts). The task analysis also identified the skills, knowledge, and attitudes required for successful task performance, in successive order of execution.

Design

The output of the design phase was the design document for the training product. The first stage of this phase determined criterion guidelines needed to evaluate systems' engineer performance. This criterion reflected the minimum requirements necessary for engineers to successfully perform e-beam lithography procedures. Next, job tasks were converted into job performance objectives in order to precisely measure trainee performance. These job performance objectives were sequenced and organized into training modules. Finally, a design document of required instructional content was developed to meet the prescription of job performance objectives. This design document included plans for instructional management, including individualized and self-paced instructional methodologies. After the design document was produced, an accurate cost estimate was determined for the development and implementation of the training product. Prior to moving onto the next phase of the instructional system, it was important that a thorough review and evaluation of all training design materials developed thus far

occurred between the instructional designers, Grumman GRO, and e-beam lithography SME's.

Development

The output of the development stage was a deliverable training prototype based on the design document from the preceding phase of the instructional system. The first stage of this phase was the determination of appropriate media and methods for instructional delivery. Factors considered were cognitive, psychomotor, and affective learning categories, training setting, training costs vs. available funds, media characteristics, and effectiveness of media in meeting instructional goals. A computer assisted expert system and job aid were selected as the appropriate media. Next, review and selection of existing materials were performed in order to avoid unnecessary reproduction. This included the review of existing video footage. Finally, all other training materials sited in the design document were developed. These materials were software and courseware requirements, job support aids, and training manuals.

Implementation

At this stage in the instructional system paradigm, the training product was ready to be implemented. The training was administered to a sample of the target population and formatively evaluated. In some cases the tasks did not meet all specified criteria. The required phases were reiterated until all task criteria were satisfactorily met. Also, it was necessary to train the staff how to operate the training system. At this

point, the training prototype became a marketable training product.

Evaluation

During the development phase, the training program was formatively evaluated against predetermined criterion. The evaluation was implemented with one-on-one groups. It was the intention of this phase to modify the training, and verify that it enabled the instructional goal and objectives. After training implementation, a summative evaluation was performed. This evaluation measured training effectiveness.

It is important to note that although the evaluation phase is defined by the ISD model as a separate phase, it is not independent from the preceding phases. It was imperative that evaluation occur at all phases of the ISD process, to ensure a proficient training program.

Summary

Prior to training, the existing performance of systems integration engineers at Grumman GRO and IBM organizations was identified as inadequate. IBM and Grumman GRO presented S/TP with a request for information concerning formal Electron Beam Lithography training. S/TP agreed to a prototype training effort for a portion of the original statement of work. The ultimate purpose of the project was to guide qualified systems engineers in the integration of the EL-3+ device. A thorough analysis of training requirements resulted in the delivery of a computer-based expert system and job aid. It was assumed the expert

system and job aid would be used as a reference for electron beam lithography procedures.

CHAPTER 2

ANALYSIS

Introduction

The analysis phase answers the question, what should be trained to whom? Inadequate analysis of training requirements results in a waste of visible dollars invested in training materials, employee time, and designer effort. Even more significant are the lost opportunity costs: the hidden costs of employees who have not been trained in the skills they need to fully utilize the technologies required by their jobs (Clark, 1989). For this reason, the analysis phase is perhaps the most critical of the instructional systems development process.

The analysis phase began with the needs analysis. The needs analysis verified training validity by identifying appropriate solutions to present performance deficiencies. Based on these solutions, an instructional goal was formulated. A media analysis was performed to identify media requirements. Related theories were presented to support the instructional strategies used for efficient training development. Finally, a schedule, design, and budget plan were formulated.

Needs Analysis

A needs analysis answers the question, "What are the best solutions to a performance problem; and if training is one solution, who needs training on what?" (Clark, 1989). A need is defined by Burton and Merrill (1977) as the discrepancy between the way things are and the way things ought to be. The

instrument used to collect data was verbal interviews with GRO SME's and management. Five people were interviewed. Appendix A describes the questions asked and a summarization of the data collected. From this data, the following categorizations were identified:

Current Performance: Systems integration engineers integrate, test, and troubleshoot devices used for electron beam lithography. Integration procedures may be performed differently, with similar outcomes. However, these different approaches often confuse new engineers. Due to the complexity, criticality, and frequency of tasks performed, engineers have very specialized roles and responsibilities. All roles require the diagnosis of system problems and failures. However, only a limited number of engineers have the ability to perform these diagnostic procedures.

Desired Performance: Systems integration engineers integrate, test, and troubleshoot devices used for electron beam lithography. All procedures are performed according to standardized criteria. Engineers have specialized roles but are able to perform procedures outside their specialty. All engineers perform diagnostic procedures required of their role in the integration process.

From these categorizations, the following problem statements were developed:

Problem Statement 1: Engineers do not perform procedures according to standardized criteria. Consequences include poor wafer quality, re-work of wafer writing, and device downtime.

Lack of standardized procedures results from:

- Informal OJT- Procedures trained are contingent upon who did the training.
- Lack of documentation- No written form of standardized procedures exists for reference.
- Dynamic nature of the technology- Because electron beam lithography is fairly new to the wafer writing industry, improvements and modifications to the technology occur often. As the technology matures, procedures and performance criteria change.

Problem Statement 2: Engineers have very specialized roles and responsibilities. Consequences include device downtime if an engineer is not available to perform tasks in their area of specialty. Assignment of specialized roles results from:

- Complexity and number of tasks.
- Criticality of tasks to successful e-beam integration.
- Infrequency of which many tasks are performed.

Appendix B outlines how each beam bring up procedure was rated according to complexity, criticality, and frequency of performance. The rating scale used was one to five, or low to high respectively. Three SME's were asked to rate the procedures according to average engineering performance. However, the designers believe the ratings were based closer to their own subject matter expertise. The average rating of task complexity was 3.3, criticality was rated as 3.6, and frequency of performance was rated as 1.5. The following results were concluded:

A. Due to the complexity and number of tasks required for beam bring up procedures, it would be impractical to expect each engineer to perform these tasks from memory. It was indicated during this analysis that very few people in the United States understand all of the steps required of e-beam technology. Therefore, it would be overly ambitious to actually train engineers in this field.

B. The criticality of steps is too important to be performed from memory. The repercussions of a mistake may result in millions of dollars of damage to the system. Also, there are some dangers to human safety as a result of performance carelessness.

C. The infrequency in which many tasks are performed may ultimately result in forgetting standardized procedures.

Problem Statement 3: Diagnostic procedures can only be performed by a limited number of qualified engineers. Consequences include device downtime if the engineer is not available to perform tasks in their area of specialty. Lack of qualified engineers for diagnostic procedures results from:

- Limited written documentation of standardized diagnostic procedures.
- The complexity of diagnostic procedures.
- The large number of e-beam variables and conditions involved in diagnosis of problems.

Gagne and Briggs (1979) warn "of the danger of too quickly concluding that any performance gap observed may be best solved

by education or training." For this reason, the designers investigated whether non-instructional variables were the cause of performance deficiencies. It was concluded that the only obstacle in performing desirable tasks was a lack of knowledge by engineers. In general, engineers who could not perform specified tasks had not done so in the past. However, due to the infrequency of which some tasks were performed, "forgetting" was a performance factor. It is necessary to note that there were informal indications that dissemination of some e-beam methodologies by knowledgeable engineers was a problem. Some engineers felt that volunteering valuable information threatened their job security. As a result, it was acknowledged that this may negatively effect the performance of other engineers.

As a result of the data collected during the needs analysis, the designers confidently answered the question, who needs training on what? It was determined that the training content would include normal integration procedures which would be enhanced by diagnostic and troubleshooting procedures. Due to the criticality, complexity, and frequency of tasks performed, the following training requirements were identified:

1. access to procedures in real-time
2. readily available signals when to perform tasks
3. sufficient direction of how to perform tasks (Spector)

Based on these requirements and the assumption that engineers had some previous training, an expert system and job aid, not comprehensive training, were identified as the best

solution. These tools would serve to improve the performance of e-beam engineers and:

1. reduce probability of errors in procedures not performed regularly
2. enhance retention of the large number of tasks
3. ensure correct performance of critical procedures (Spector)

Job Task Analysis

According to Branson (1977) training needs in industry are often derived from a job analysis. Specifically, the information collected from the job analysis helped the designers focus the tasks to be trained, as well as define the current and desired job performance definitions.

The designers began the job analysis by collecting basic job information. As a result of verbal interviews with GRO management and systems engineers, the following definitions were formulated:

Job Title: Systems Integration Engineer

Job Description: A systems integration engineer is required to integrate, test, and troubleshoot devices used for electron beam lithograpy. These devices use electron beams to write information onto computer chips. This job is performed in an environmentally controlled, information secure laboratory. This process includes the integration of raw materials and equipment in accordance with design specifications developed by IBM. These devices are fully tested and operational prior to the delivery of the system to the IBM, Fishkill plant. Testing includes troubleshooting

and repair of the system if not fully operational. During schedule problems the engineer must be available for possible overtime and weekend work. Engineers must be available for on-site technical support at the IBM, Fishkill plant. This includes travel from a few days to two years.

Because cost and budget constraints restricted training of all procedures, the job analysis helped focus on tasks that would be included in the training. As a result of interviews with SME's, the designers began dividing the job into several non-overlapping functions, or AOR's (areas of responsibility). These AOR's define the major responsibilities which result in specific outputs distinct from other outputs (Clark, 1989). Appendix C describes how the AOR's and major duties for e-beam integration were defined according to digital, analog, mechanical, and column engineering responsibilities. From these AOR's, it was determined that beam bring up procedures would include digital, analog, and column engineering responsibilities. Mechanical engineering procedures were identified as future training efforts.

Target Population Analysis

Audience includes approximately ten engineers. The age range is from 25 to 60 years. All engineers have a minimum of either a B.S. in physics or electrical engineering. All engineers have some experience with electron beam lithography. Many have experience on the current EBL-3+ device. Some have experience on-site at IBM, Fishkill in e-beam technical support. Length of service ranges from two to ten years.

Organizational Constraints

At the start of this project it was underscored by management that delivery of e-beam devices was top priority. Therefore, training development could not effect the device delivery schedule. Although the designers did their best to adhere to their own schedule, there were instances when the configuration of the device could not be changed, or SME's were unavailable for consultation. This caused problems particularly during the analysis phase of the project.

A second constraint was the requirement of IBM IWPS hardware and software for CBT/IVD media development. GRO management felt that since the EBL-3+ was an IBM product, training should also be delivered on an IBM product. This was determined prior to a comprehensive media analysis.

Instructional Goal

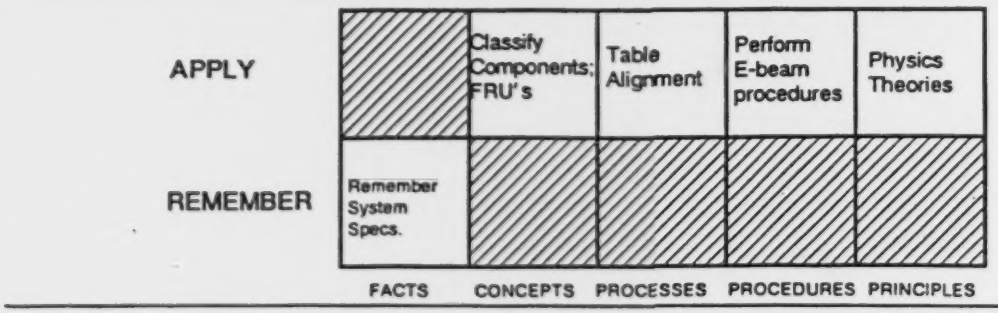
Given a computer-based job performance aid and expert system, and no assistance from other engineers, the systems integration engineer will bring up a beam for the purpose of electron beam lithography. The beam must be aligned and adjusted according to system specification and standardized procedures. The methodology used for determining this instructional goal was derived from Dick and Carey (1985).

According to Gagne's learning outcomes, this goal was classified as an intellectual skill. Gagne (1987) defines an intellectual skill as "knowing how" or procedural knowledge. A content-performance matrix was developed to determine desired level outcomes. The model for this matrix was based on Merrill's

Content-Performance Matrix (1987). Figure 1 presents a two-dimensional matrix with five types of content along the horizontal axis and two levels of performance along the vertical axis. It was concluded that "remember" outcomes would include facts necessary to perform e-beam procedures. Concepts, processes, procedures, and principles would represent "application" level outcomes. Concepts and procedures necessary for e-beam integration were addressed by the job aid and expert system. Processes and principles were addressed by the demonstration training module (Von Der Linn, 1990).

Figure 1

Content Performance Matrix



These expected level outcomes were based on the following major tasks and topics:

1.0 Verify Initial Conditions

2.0 Power Up and Initialize System

3.0 Align Beam

4.0 Adjust Astigmatism

5.0 Perform Double Deflection

6.0 Perform Shaping

Media Analysis

The purpose of this analysis was to identify CAI media requirements necessary to meet training goals. Because the training goals reflected two categories, guidance in integration procedures and troubleshooting assistance, each outcome was treated differently during this analysis.

Guidance in Integration Procedures:

The model for media selection used by the designers was A Better Model for Media Selection, developed by Levie (1975). Figure 2 displays how this model was applied to e-beam media selection. The first step of the model assumed valid learner, task, and environmental analyses were performed. This information was collected during the needs analysis phase.

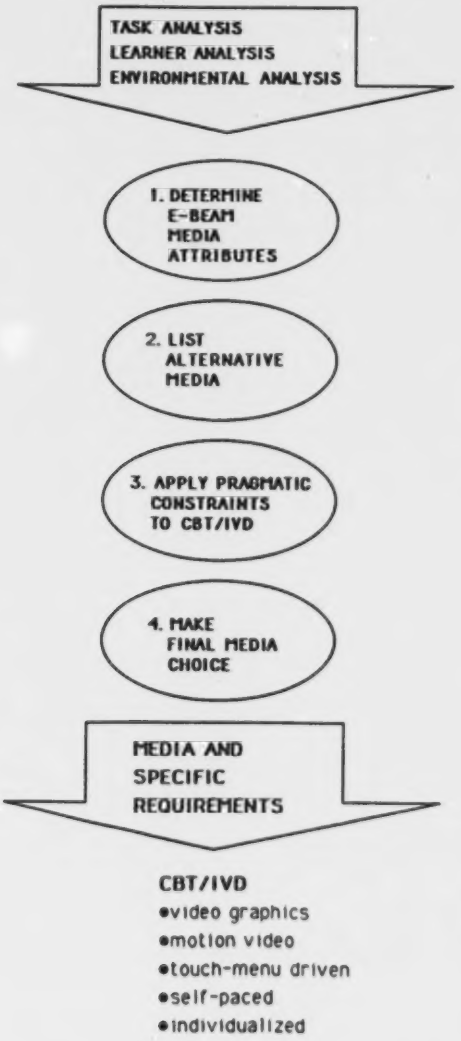
Step 1: With a CAI job aid identified as the required media and method, the designers began step one of Levie's model. The Media Attribute Classification System, presented in Table 1, was designed to focus on specific media requirements.

1. Sign Vehicles: Sign Vehicles are symbols produced for the purpose of making references to objects, concepts, and events the designers wished to communicate. By defining sign vehicles, the designers were able to identify content best presented as digital signs or words and iconic signs or pictures. The digital signs identified were e-beam procedures and step list, numerical meter readings and tolerance levels, and troubleshooting symptoms. The iconic signs identified were component parts and locations, waveforms, and switch and potentiometer positions.

2. Realism Cue Characteristics: Realism cue characteristics

Figure 2

A Better Model for Media Selection



were identified in order to sufficiently replicate realistic conditions with which the engineer performs. Conditions that must reflect acceptable levels of detail were identified as waveforms, switch position labels, and component locations and labels. Due to the criticality of waveform discriminations, the

Table 1

Levie's Media Attribute Classification System

SIGN VEHICLE CHARACTERISTICS
Digital Signs
Iconic Signs
REALISM CUE CHARACTERISTICS
Amount of pictorial detail
Color
Motion
Dimensionality
Auditory effects
SENSORY CHANNEL CHARACTERISTICS
Vision
Audition
Touch
Multi-channel presentations
LOCUS OF CONTROL CHARACTERISTICS
Referability
Fixedness-flexibility of pace
Fixedness-flexibility of sequence
RESPONSE ACCEPTANCE CHARACTERISTICS
Response demands
Feedback provisions
Adaptiveness

designers felt graphically simulated waveforms would be unacceptably low in fidelity. Therefore, motion video of waveforms was necessary. Color, dimensionality, and auditory effects were not applicable factors.

3. Sensory Channels: The sensory channel used during actual performance of procedures was visual only. In order to successfully perform e-beam tasks the learner must visually discriminate between stimuli, recognize symptoms, and identify

component and switch positions. Audition channels were not applicable because no auditory cues were necessary to perform procedures. Touch was also determined as not applicable. There was a psychomotor component to e-beam procedures, indicated by such tasks as "depress key," "turn potentiometer," "flip switch." However, the designers were concerned with the cognitive cues that result in these psychomotor skills.

4. Locus of Control: The required locus of control represented high referability and flexibility of pace and sequence. This would allow real time reference of only those steps necessary to perform required tasks at the users' own pace.

5. Response Acceptance Characteristics: The response acceptance characteristics were identified as not applicable. Performance of tasks would occur on actual equipment, and would not be directly assessed by the training product. Therefore, response feedback would be provided on the job by production assessments and supervisory performance observations.

Step 2: Because InfoWindows Presentation Systems was designated as the required media, Step 2 of the model was not performed.

Step 3: Step 3, Apply Pragmatic Constraints, was performed to identify media constraints that would effect implementation of the CBT job aid.

1. Production Constraints: Production constraints are high during CBT development. Costs were estimated at $182,000 with two person years worth of effort. However, production hardware was not an issue. S/TP had an in-house, fully functioning video production facility. In terms of the designers' preference, they

had successful and significant experience in developing CBT/IVD. There were some formative evaluation risks. Changes identified by the formative evaluation would result in additional re-taping, editing, and disc re-pressing efforts.

2. Dissemination Constraints: Although production constraints may be high, the advantage of CBT/IVD was the low risk of dissemination constraints. Once a CBT/IVD program is developed there are few recurring costs. The only identified dissemination constraint was additional InfoWindow hardware costs. It was agreed by GRO, IBM, and S/TP that low dissemination constraints outweighed the production constraints.

Step 4: The most desirable media selection choice for any type of training is the media that closely reflects the conditions under which the learner is expected to perform. However, it is necessary to balance fidelity requirements and cost-effectiveness. Based on organizational and pragmatic constraints, a CBT/IVD job aid was identified as the most desirable choice. The data collected from A Better Model for Media Selection helped define the specific media requirements. It was concluded that the training would present visual information only. This would include text, graphic, and video information. High level, detailed graphics of component locations, switch positions, and labels were identified as required realism factors. Due to the criticality of waveform discriminations, motion video of waveforms was necessary. A self-paced, touch-menu driven format was identified as necessary to meet locus of control characteristics.

Troubleshooting Assistance:

During the job analysis, the following verbs were utilized to describe troubleshooting procedures of step 4.0, adjust astigmatism: debug, diagnosis, interpretation. According to Frenzel (1987), an expert system is suitable for these problem areas. In addition, astigmatism troubleshooting:

1. requires human expertise
2. has a high payoff
3. does not require common sense
4. has a narrow focus
5. is moderately difficult
6. can be solved with knowledge
7. has a minimum number of solutions

These factors represent suitable requirements for an expert system solution to astigmatism troubleshooting and diagnosis. In addition, the personnel, hardware, and schedule resources available for expert system development were verified according to the following checklist, extracted from Bielawski and Lewand, (1988):

1. A domain expert was available for consultation.
2. A competent knowledge engineer was available to transfer information into a comprehensive knowledge base.
3. An expert system programmer was available.
4. Hardware was available for expert system development, specifically the InfoWindows system.
5. Development and delivery environment were compatible since they were the same system.

6. Sufficient time was available for expert system development.

7. S/TP would be responsible for maintenance of the system.

Prolog was the expert system shell chosen for development. This was because the programmer had significant experience with Prolog.

As a result of the media analysis, a CBT/IVD job aid and computer-based expert system were identified as media requirements. A summary of the differences between the CBT/IVD job aid and the expert system, based on Bielawski and Lewand (1988), is outlined in Table 2.

Table 2

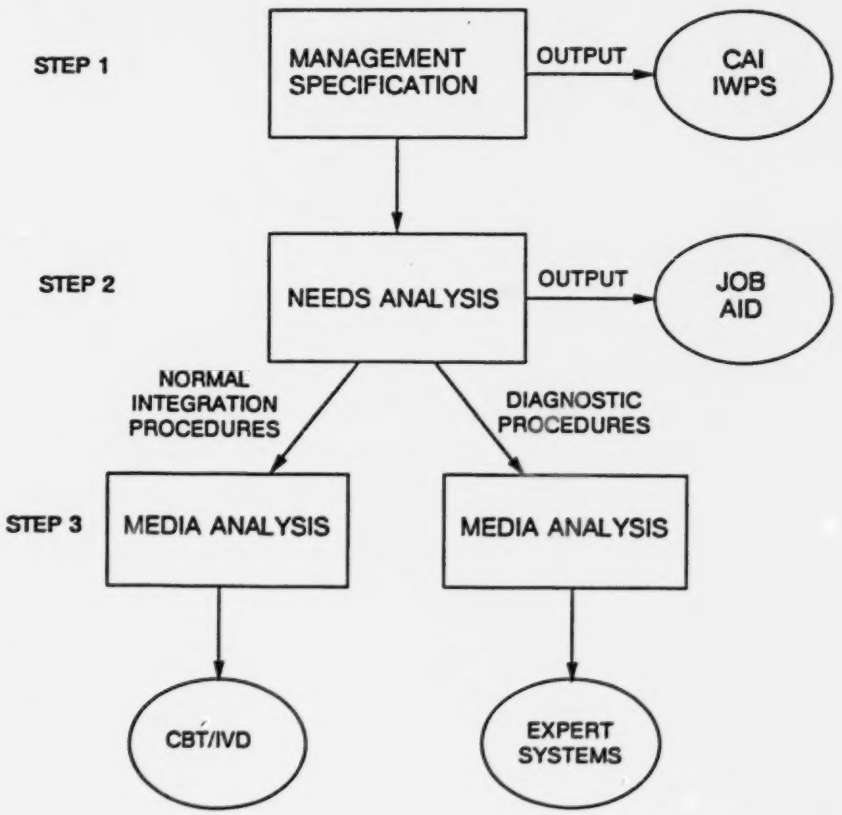
Differences Between Job Aid and Expert System

	CBT/IVD Job Aid	Expert System
1.	requires complete set of data to run	can function without a complete set of data
2.	uses algorithms in solving beam bring up problems	uses heuristics in solving beam bring up problems
3.	produces unique solution to beam alignment problems	may produce more than one solution to beam alignment problems
4.	generates results that are certain	may generate uncertain results
5.	is based on a top-down approach or deductive logic	is based on a bottom-up approach or inductive logic

At this point, the final phase of identifying all media and method requirements was completed. The phases and outputs are presented in Figure 3.

Figure 3

Media and Method Stages and Outputs



Literature, Existing Course, and Material Review

The designers surveyed literature on learning theory, technical training, and perceptual and design theory. In addition, articles and books on computer-based instruction and expert system development were reviewed.

Related Theory

One of the first taxonomies of learning was presented by Bloom. The three learning domains defined by Bloom, Krathwohl, and Masia (1956) were:

1. Cognitive Domain: The area that involves imparting knowledge.
2. Affective Domain: Emotional development, which embraces feelings, interests, attitudes, and values.
3. Psychomotor Domain: Development of physical skills.

This project reflects cognitive learning outcomes. Table 3 outlines the highest levels of cognitive learning as application and analysis outcomes. Knowledge, comprehension, and application

Table 3

Bloom's Taxonomy of Desired Learning Outcomes

Behavior / Task	KNOW.	COMP.	APPL.	ANAL.	SYNTH.	EVAL.
1. Verify initial conditions	*	*	*	Identify Recognize		
2. Power up and initialize system	*	*	Perform Manipulate			
3. Align Beam	*	*	*	Distinguish Identify		
4. Adjust Astigmatism	*	*	*	Discriminate Recognize		
5. Perform Double Deflection	*	*	*	Distinguish Identify		
6. Perform Shaping	*	*	*	Discriminate Recognize		

* = Prerequisites

skills are prerequisites for reaching these levels. Behavioral objectives were based upon these taxonomies in the cognitive domain.

Gagne (1987) introduced a more prescriptive taxonomy. In addition to the five categories of learning outcomes, Gagne described the conditions under which each outcome is achieved. Particularly important are the descriptions of instructional strategies the designers can control to produce desired learning outcomes. The five categories of learning outcomes are:

1. Intellectual Skills: Ability to manipulate previously unencountered data.
2. Verbal Information: Ability to "tell" a fact or set of events by using speech or written communication.
3. Cognitive Strategies: Skills that manage one's own learning, remembering, and thinking.
4. Motor Skills: Ability to execute movements in a number of organized motor acts.
5. Attitude: Mental states that influence the choice of personal actions.

Similar to Gagne's theory that educators can control external learning variables that produce desired outcomes, Fleming and Levie (1978) identify perceptual events the designer can also control. While it is impossible to predict exactly what an individual will perceive in a given situation, it is possible to identify the major ways perceptions will vary under various conditions. These principles guided the designers in the

arrangement of perceptual conditions for the computer-based job aid and expert system.

Clark (1989) adapted Merrill's content performance taxonomy to include instructional strategies of the "remember" and "apply" performance level outcomes. The strategies describe prescriptions for teaching four types of technical information:

1. Facts: One of a kind associations among concepts or individual specific items.
2. Concepts: Class of items that share common features and are known by a common name. Most technical training involves many concepts associated with the procedures employees need to learn for effective job performance.
3. Procedures: Series of clearly defined steps which result in the achievement of a job task. Procedures may be linear or branched. Results in near-transfer training.
4. Principles: Guidelines of when to perform procedures in a variety of job related context. Results in far-transfer training.

Literature Review

1. Campbell, J. O., and others. (Oct. 1984). Interactive videodisc design and production workshop guide. (Contract Number: MDA-903-78-C-2023). Army Research Institute for the Behavioral and Social Sciences.

This article provided an overview of the entire videodisc authoring and production process. The topics presented include project planning; design and authoring; preparation of production lists and scrips; production of video test frames, animations,

photographs and print; post production and premastering.

2. Dear, B. L. (1987, Summer). AI and the authoring process. IEEE Expert, 17-23.

This article described the shared ideas and combined efforts of artificial intelligence and CBI researchers. Factors inherent to AI techniques and CBI methodologies were presented, and the ways in which both can improve courseware were discussed.

3. Harmon, P., and King, D. (1985). Expert systems: Artificial intelligence in business. New York: John Wiley and Sons, Inc., 177-194.

This chapter "walks through" the actual development of a small expert system. Expert system concepts were described. A procedural description of steps involved in expert system development was presented.

4. Maher, J. H., and Ingram, A. L. (1989). Software engineering and ISD: Similarities, complimentarities, and lessons to share. Paper presented at the annual meeting of the Association of Educational Communications and Technology, Dallas, Texas.

This article described the similarities of the problems shared by instructional systems development and software engineering. The ways in which ISD can learn from software engineering methods were presented. The methods included project planning, reviews, configuration management, and designs to make procedures more effective and consistent. The ways in which software engineering can learn from ISD non-technical issues were

described. These issues included human factors, organizational design, and team building.

5. Stone, D. E., Hutson, B. A. (Oct. 1984). Computer-based job aiding: Problem solving at work. (Contract Number: N00014-80-C-0372). Personnel and Training Research Programs Office, Office of Naval Research.

This article described an ongoing effort in understanding the processes people employ in reading technical material and the ways in which computer-based job aids can assist people in doing complex tasks. The study determined how subjects engaged in an assembly task used a detailed information structure to meet their information needs. It was concluded that it may be useful to include a variety of information types in a technical information system for job aiding, and to allow subjects a high degree of control over requests for information.

6. Welsh, J. R., and Wilson, B. G. (1987). Expert system shells: Tools to aid human performance. Journal of Instructional Development, 10,(2), 15-19.

This article examined expert system shells and the role a microcomputer-based expert system can play as an intelligent job aid. Characteristics of traditional and automated job aid techniques, and the role of intructional designers in developing expert system were described.

7. Wittrock, M. C., and Lumsdaine, A. A. (1977). Instructional psychology. The Annual Review of Psychology, 28, 417-439.

This article was a comprehensive review of the most popular and current theories of instruction. The ways in which educators must understand the effects of instruction upon learning and memory, and the cognitive process used during learning were presented. Cognitive processes presented included attention, motivation, reinforcement, verbal and imaginal encoding, storage, and retrieval.

Survey of Existing Courses and Materials

Few courses or materials exist. Due to the sensitivity and complexity of the technology documentation, electron beam lithography research and documentation were of little use to the designers. Because no written procedures existed, the designers literally began from scratch. The system familiarization tape, produced as a training requirement, did provide some video and graphic footage for the job aid.

Plan for Project

As a result of the needs and media analyses, training requirements and media attributes were identified. From this, a plan for the design and development efforts was formulated. The project began May 1989 and was completed May 1990.

Estimated Student Effort

Depending on the number and type of procedures referenced from the job aid, a single learner may require a few minutes to eight hours of effort. Similarly, the expert system may be referenced for a few minutes or up to one hour.

Project Plan

The designers used both the PERT and Gantt charts to

formulate a project plan. Appendix D describes the sequential dependencies and schedule variables outlined by these methods. All events were assigned immediate predecessor relationships, and estimated completion times. From this, earliest start and finish times, latest start and finish times, and slack times were calculated. This identified the time constraints the designers had to work within. A critical path was identified. This formulated the events the designers had to monitor closely. A slip in schedule of any of the critical path events would push back the projected finish date, which was estimated at 56.5 weeks after turn on. In addition to the schedule and budget plan, a design document was developed. The design document, outlined in Appendix E, described the training approach, strategies, and goals.

Budget

Budgetary factors that effect budget decisions were not available to the designer. These factors were handled by S/TP's Business Operations Department. The following estimates were determined: materials = 20.5 k, instructional systems development = 136.0 k, support personnel = 25.5 k. This adds to a grand total of 182 k, where k = $1,000. A further cost breakdown is outlined in Table 4.

Summary

The analysis phase identified e-beam performance deficiencies. The deficiencies resulted from a lack of standardized e-beam procedures, the specialized engineering roles and responsibilities, and the inadequate ability of engineers to

Table 4

Project Cost Breakdown Structure

Description	Cost	Total
Materials		
Hardware	9.5 k*	
Software	5.5 k	
Miscellaneous requirements	2.0 k	
Videodisc Mastering	3.5 k	
		20.5 k
Effort		
Analysis	33.75 k	
Design	33.75 k	
Development	46.0 k	
Implementation	11.25 k	
Evaluation	11.25 k	
		136.0 k
Graphic Artist	6.0 k	
Technical Support	6.0 k	
Management	13.5 k	
		25.5 k
	Total Cost	182.0 k

*k = $1,000

perform diagnostic procedures. A computer-based job aid and expert system were identified as appropriate training solutions. The designers categorized the instructional goal in the intellectual domain. Finally, a project plan and cost breakdown structure were developed.

CHAPTER 3

DESIGN

Introduction

The design phase of the instructional systems model involves the molding of all previously gathered information efforts into a presentation format that will facilitate exciting and worthwhile learning. This task is both a science and an art and requires a strong sense of intuition by the designer.

The design phase began with the identification of tasks to be trained and entry behavior requirements. These tasks were transformed into instructional objectives, which were logically sequenced and grouped. Next, the strategies for implementing the CBT/IVD and expert system training were determined. Finally, the methods for evaluating the instruction and the review of the existing literature and courses were considered.

Instructional Task Analysis

An instructional task analysis was performed to identify the subskills required for successful e-beam integration. The task analysis was a product of observing engineers perform beam bring up procedures, as well as "picking the brains" of these engineers. According to Clark (1989), SME's generally make four errors when presenting lesson content. They:

1. organize the content around the structure of their expert knowledge.
2. fail to distinguish between content that is nice to know and that which is essential to the job.

3. leave out important underlying information.
4. tend to cluster too much information together, neglecting to break it into short, logical sections.

All of these problems were addressed by the designers at some time during the task analysis. However, the solution was to ask questions, questions, and more questions about lesson content. It was also important for the designers to build a good rapport with the technical experts. By making the SME's feel comfortable and relaxed, they were much more cooperative and helpful.

Because training development could have no impact on integration schedules, a videotape of the beam bring up procedures was used as a task analysis reference. This allowed the designers to analyze the procedures repeatedly, and not interfere with the work of engineers unless absolutely necessary.

Due to the technicality and number of steps involved with beam bring up procedures and the inexperience of the designers with the subject matter, the decision was made to initially identify the tasks by representing them visually on hardcopy graphics. As the designers became familiar with the component names, locations, and functions, the storyboards were converted into verbal task lists.

Beam bring up tasks represent near-transfer training. Near-transfer training is procedural, involving specific steps to be followed, more or less the same way each time. These procedures reflect both linear and branched formats. The normal integration procedures, presented by the CBT/IVD job aid, were basically linear and generally had to be performed in a specific

sequence. The troubleshooting procedures, presented by the computer-based expert system, included many branched procedures. All of the procedures were identified as a result of four instructional analysis steps. They were:

1. Verification of job functions identified by the job analysis.
2. Definition of job tasks associated with each function. A job task is an activity that results in a specific outcome and contributes to the accomplishment of that function.
3. Definition of steps associated with each task. The 15 step rule was applied during the analysis. This resulted in more manageable lessons and modules.
4. Definition of hidden mental skills. Prior to this point in the analysis, most procedures reflected tasks in the psychomotor domain. However, it was important to identify the mental judgments or decisions necessary to perform these procedures and tasks. Most mental skills were the following types:
   A) Discriminations: For example, during beam alignment procedures an engineer must use the keypad. In order to do this, the engineers must discriminate between the keys on the keypad. Discriminations involve concepts- to know what a keypad is, and factual information- what character each key corresponds to.
   B) Factual information: For example, the engineers need to know system specification requirements associated

with each step and procedure.

C) Decision criteria: These hidden mental skills were necessary for troubleshooting procedures, and therefore designed for the computer-based expert system. For example, the engineers need to identify waveform criteria in order to determine a specific course of action.

After the functions, tasks, steps, and hidden mental skills were identified, a procedures list was developed. The comprehensive task analysis cannot be included in this document due to the sensitivity of its content. However, an example of the expert system task list is shown in Table 5.

Table 5

Example of Task Analysis Procedures List

FUNCTION =>	4.0 Adjust Astigmatism
TASK =>	4.1 Set up SSM FRU
STEP 1 =>	4.1.1 Set BEAM CONTROL switch on
STEP 2 =>	4.1.2 Set LSCAN switch to ON ELEC
STEP 3 =>	4.1.3 Set DISPLAY switch to TRANSMISSION
HIDDEN MENTAL TASKS:	1. Locate SSM on rack 2. Locate BEAM CONTROL, LSCAN, DISPLAY switches on SSM 3. Discriminate correct switch settings

The task analysis was reviewed by SME's and the designers to confirm that the tasks were:

1. Complete: All steps necessary to perform functions were present.
2. Finite: Each subtask had a specific input and output.

3. Unambiguous: Each subtask could only be interpreted in one way.
4. Operational: Each subtask stated specifically what the learner needed to do or know.

Most tasks were reviewed on paper only. Because the configuration of the e-beam system could not be modified, most tasks, steps, and procedures could not be directly performed and verified on the system. Because the designers had no control over this constraint, it was agreed that some tasks may need to be modified in the future when they could be verified against the actual equipment.

Instructional Objectives

Performance objectives describe specifically what the engineers are expected to do and know in order to successfully perform beam bring up procedures. They do not describe what the CBT/IVD job aid and expert system will be doing or what the designers will be doing.

Mager (1984) presented the concept of performance objectives in the 1960s. The three elements of a performance objective are:

1. Behavior: The skill or task to be performed. This verb directly corresponds to the skill or task identified in the instructional analysis. It should be a measurable action or behavior, and reflect the intellectual and/or behavioral skill the engineers need to perform. Because the goal of the training is to assist engineers in "doing," performance verbs reflecting the

application and analysis levels were used to describe desired behavior.

2. Condition: The conditions of the actual environment with which engineers must perform. This describes the helping and limiting conditions that will exist when the engineers are performing integration procedures.
3. Standard: The criteria used to evaluate the performance of the learner. The task list would be the performance checklist criteria for determining whether the objectives were successfully achieved by the engineers.

Based on these elements, the performance objectives for the expert system were:

1. Given a system whose beam has been properly aligned and a computer-based expert system, the engineer will verify initial conditions for astigmatism procedures. Verification must include X-Y table and Spot Shape Monitor conditions.
2. Given a system whose initial conditions have been verified and a computer-based expert system, the engineer will determine whether Stig 1 is on-axis or off-axis. This determination will be based on specific waveform criteria.
3. Given a system where Stig 1 has been determined as either on-axis or off-axis and a computer-based expert system, the engineer will perform Lens Supply adjustments. Adjustments will be based on specific waveform criteria.

4. Given a system which has had required Lens Supply adjustments and a computer-based expert system, the engineer will perform Condenser Stig 1 adjustments. Adjustments will be based on specific waveform criteria, and whether Stig 1 is on-axis or off-axis.

The performance objectives for the CBT/IVD job aid were:

1. Given a system whose hardware has been properly assembled and a computer-based job aid, the engineer will verify the initial conditions for beam bring up procedures. Verification will include proper hardware installation, system power on, and yoke drivers off.
2. Given a system whose initial conditions have been verified and a computer-based job aid, the engineer will power up and initialize the system. Power up and initialization must include turning on and setting up required Field Replaceable Units (FRU's) and positioning of the X-Y table.
3. Given a system which has been powered up and initialized and a computer-based job aid, the engineer will align the beam. Beam alignment must include first, second, third, and sample apertures.
4. Given a system whose beam has been properly aligned and a computer-based job aid, the engineers will perform astigmatism adjustment procedures. Astigmatism adjustments must include set up procedures and Lens Supply adjustments.
5. Given a system which has had proper astigmatism

adjustments and a computer-based job aid, the engineer will perform double deflection procedures. Double deflection procedures must include required Alignment Brightness FRU adjustments.

6. Given a system which has had proper double deflection adjustments and a computer-based job aid, the engineer will perform shaping procedures. Shaping procedures must include the proper physical set up and required adjustments in the X and Y axis.

Entry Behaviors Defined

Entry behaviors are the performance and mental skills the engineers must posses prior to using the job aid. The selection of those skills to be included in the instruction and the necessary prerequisite skills were critical. If the engineers did not posses prerequisite skills, it was likely the job aid would be difficult for the engineers to use. If prerequisite skills the engineers did possess were included in the training, the job aid would be laborious to use. After analyzing the target population and their knowledge of integration skills and procedures, it was concluded that the engineers possessed very different levels of knowledge. Because the engineers were so specialized, they were very proficient within areas of their specialty, yet unknowledgeable outside this area. The designers wrestled with how the training would meet entry behavior requirements and individualized training needs. Three alternatives were addressed concerning how to treat these issues:

1. Design the job aid for the lowest level of knowledge and

skills.

2. Develop introductory training for entry level engineers.
3. Tailor the job aid to meet the different skill levels of the engineers.

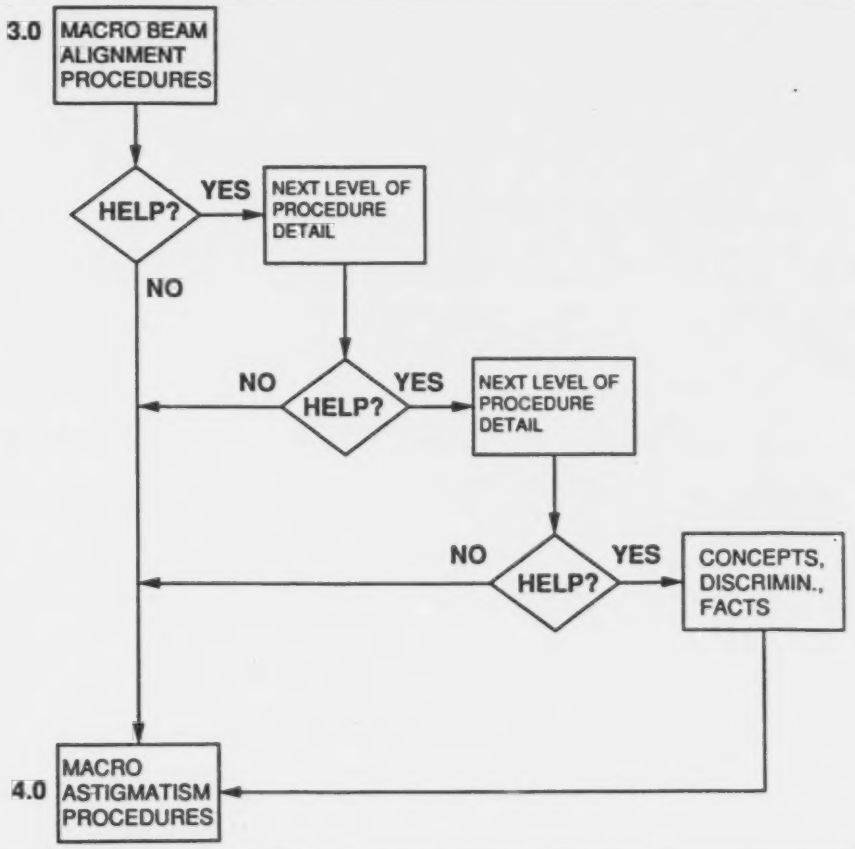
As the alternatives were further analyzed, it was concluded that alternative one might bog down engineers in content they did not need. This would frustrate the engineers and decrease the effectiveness of the training. Due to budget and schedule restrictions, option two was not feasible. However, a training demonstration was developed. This demonstration presented a sample approach the designers would take to train engineers for prerequisite skills. This may become a priority in the future, but at this stage, efforts were focused on the job aid only. Therefore, it was concluded that option three was the most appropriate for meeting prerequisite skills. As a result, the job aid would provide optional levels of help to the engineers. This strategy is outlined in Figure 4.

Group and Sequence Objectives

The sequencing of lesson content identifies the natural performance relationship between objectives. The beam bring up job itself served as the basis for defining the sequence of objectives. This was defined by Clark (1989) as job-centered organizational scheme. Because the instructional analysis represented a natural sequencing of events it was only necessary to confirm this sequence. This was done by working closely with the technical experts. The following criteria was used to make a final decision about objective sequence:

Figure 4

Treatment of Entry Behaviors and Additional Help



1. Unnecessary objectives: Are objectives nice to know but do not contribute to performance of any terminal objective?
2. Incorrectly positioned objectives: Are objectives out of sequence?
3. Unlisted objectives: Are objectives not identified but necessary in meeting a terminal objective?

In addition to the principles above, the zoom principle was applied during the development of the course outline. Reigeluth (1987) uses a camera analogy to illustrate this principle.

First, the designer should begin with a wide angle view of the content. Then they should zoom in on the details. Before moving to a different view, the lens should be brought back to the wide angle view again. This helps the learners to relate detailed information to the "big picture." Because the beam bring up procedures may include many layers of detail, and CAI screens cannot be addressed like pages in a book, the designers agreed that the learners may become easily disoriented concerning sequence of the procedures, and their relation to the "big picture." The designers determined that two strategies would support the zoom principle. First, each screen would have a corresponding task number in the upper right hand corner. According to the size of the number, the engineers could better reference where they were in the procedures. Also, in order to move onto the next menu of procedures the user was required to return to the menu from which they were currently working. This forced the user to see the immediate big picture prior to continuing with new procedures.

Learning Activities Specification

Terms such as individualized computer-based instruction, interactive videodisc, and computer-based expert system describe very broad types of instructional strategies. What these terms do have in common is that a computer delivers the training. The important question is how? There are six CAI strategies that help learners meet instructional goals. They are: instructional games, drill and practice, simulations, tutorials, problem solving, and modeling.

Although a computer-based job aid and expert system are not considered instruction because learning is not a requirement of training outcomes, problem solving is the strategy that best reflects this program. This strategy uses the computer as a tool to aid in the ability to formulate, analyze, and solve problems. The specific elements of the program that facilitated problem solving are listed in Table 6.

Table 6

Instructional Strategy Matrix

LEARNING OBJECTIVE	CONTENT	INSTRUCTIONAL TECHNIQUE	MEDIA
1.0	Initial conditions	Job Aid	CBT, IVD
2.0	Power up	Job Aid	CBT, IVD
3.0	Beam Alignment	Job Aid	CBT, IVD
4.0	Adjust Astigmatism	Expert system, Job Aid	CBT, IVD
5.0	Adjust Servos	Job Aid	CBT, IVD
6.0	Shaping	Job Aid	CBT, IVD

During the design of the CBT/IVD job aid, a number of perceptual principles were employed. Consistency of screen elements was very important. For example:

- all lesson elements were placed in the same position: icons- next, back, menu, main, branching information; task numbers; informational windows.
- all branching was standard: next icons branched to the next logical screen, back to the previous screen, menu to

the menu the procedures were being referenced from.

- consistent color was used to indicate specific lesson elements: all touch acknowledgments were confirmed by an original change in color to cyan, branching information in red.

Once the end user became familiar with available lesson capabilities, the function of these lesson capabilities, and where to find this information less perceptual time and effort would be needed to extract important information.

Storyboarding was used to document the job aid lesson design. An example of the storyboarding procedure is displayed in Appendix F. The following information was presented on storyboards:

1. Text menus: location, color, and content
2. Additional task information popup windows: location, color, and content
3. Help windows: location, color, and information
4. Conditional and unconditional lesson branching: where from, where to
5. Icon placement: location, color, type
6. Additional lesson information: location, color, content
7. Video and graphics requirements: play or still sequence, start-stop frames, special attributes.

Similar to the job aid, specific steps were required in the design of the expert system. Expert systems are a specific application of artificial intelligence technology. Expert systems are defined as computer-based programs that simulate the

thinking and problem solving process of experts in a specific domain of knowledge. This expert system uses a backward-chaining inference technique to prove a goal as true. The goal of this expert system was to advise engineers on diagnostic decisions based on astigmatism adjustment symptoms. The components of the e-beam expert system were:

1. Knowledge Base: The facts about the domain of astigmatism adjustment, and the rules for using these facts in problem solving. The facts and rules were extracted by knowledge engineers from domain experts.
2. Inference Engine: The computer program which draws an inference by comparing user supplied facts against the knowledge base.
3. User Interface: The link between the information provided by the user and the inference engine.

During the design of the expert system, the astigmatism adjustment tasks were transformed into a knowledge base. To begin, the designer determined the outputs of the expert system. These outputs were based on the four performance objectives. Next, the designer identified the conditions that resulted in the outputs. The conditions for each output were first identified by a flow chart that plotted the general flow and sequence of astigmatism procedures. The flow chart is outlined in Appendix G. Next, the designer used the flow chart to develop a decision tree. The decision tree, outlined in Appendix H, helped the designer visualize all the factors necessary in reaching each conclusion. A decision tree is named so because it branches off

like a tree. At the end of each branch is a conclusion or solution to a problem, based on specific conditions. Appendix I displays the matrix developed from the decision tree. The matrix outlined the conditions and solutions in table form. From this matrix the production rules were developed. The production rules are displayed in Appendix J. Production rules have 2 parts, IF - THEN. The IF part represents the conditions or clauses which result in a particular solution. These clauses are connected to one another by logical operators, including AND, OR, and NOT. The THEN part of the rule base represents a solution which is evaluated as true, only after each clause is proven true.

The final stage of the expert system was the design of the question screens which required yes or no responses, and direction screens describing corrective actions. The expert system screen designs are displayed in Appendix K. The screens were designed for ease of use according to the following criteria:

1. screen content was simple and sparse
2. keystrokes and types of keystrokes kept to a minimum
3. the designer assumed that the user was knowledgeable and required neither extensive elaboration of questions or detailed descriptions of keystrokes.

Assessment System Specification

Because a job aid is not designed to replace learning, the reference to "learning" in this document will imply desired performance of procedures on the job. Although the job aid and expert system will not include any tests, a formal plan of how

performance will be measured was developed. Because performance of correct beam bring up procedures was the goal of the training, the tasks and steps that enabled successful performance of beam bring up procedures would be the criteria used in evaluating training objectives. Specifically, the task listing would be used as a checklist during performance assessment. The designers planned to observe engineering performance and verify whether tasks did or did not enable successful performance of objectives. Of those objectives not correctly performed, it would be determined whether:

1. The job aid or expert system did not provide any assistance for meeting the objective.
2. The job aid or expert system provided inaccurate assistance for meeting the objective.
3. The job aid or expert system needed to provide additional information for meeting the objective.

Evaluation System Specification

The evaluation plan occurred in two phases. The first phase reflected formative evaluation. The three groups planned for during formative evaluation were one-on-one, small group, and field trial groups. Information gathered from the formative evaluation would identify ways the training could be modified to be more effective. Therefore, the formative evaluation was considered a development tool. During one-on-one evaluations, the designers planned to perform observations in close proximity to the engineer as they used the job aid and expert system. During small group evaluations the designers would make

observations from a farther distance than one-on-one trials. The designers would not be present during field trials. A performance checklist, representative of the task list, would be used to determine whether the job aid enabled the engineers to perform beam bring up procedures.

The second phase of the evaluation plan represented the summative evaluation. This phase reflected implementation of training in the real environment for which it was developed. The job aid and expert system were designed to be set up in close proximity to the actual equipment. All engineers would be instructed in how to use the system. The designers would not be present during this evaluation. Summative evaluation information would be collected from engineering reaction surveys, discrepancy reports, and supervisory observations. The supervisors would be given a performance checklist to evaluate how well the steps assisted the engineers in performing beam bring up procedures. The Kirkpatrick Evaluation model (1987) would be used to measure the four levels of summative evaluation. These levels are: reaction, learning, behavior, and results.

Learning Transfer System Specification

The transfer of training specifications was based on Broad (1982). Broad's research presented insightful ways of improving the often disappointing transfer of training results measured after training. She indicated that more effort must be employed in gaining management involvement and support in transfer of training, rather than concentrating on ways the training itself can be improved.

Review and Selection of Existing Materials

The only existing materials identified during the analysis phase were videotape footage from the training familiarization tape. Some of the footage was selected to be stored on videodisc. The footage selected included a short computer graphics animation simulating what happens during electron beam lithography. This was used as a motivational introduction to the job aid and expert system. Also, video of engineers actually performing some procedures was used to model correct procedures.

Summary

The design phase yielded a task analysis which produced a listing of all steps required to perform beam bring up procedures. From this listing, objectives were developed which described the specific performance required of e-beam engineers, the conditions under which the engineers performed, and the criteria by which their performance was evaluated. Because the tasks were procedural, and generally must be performed in a specific order, there was a natural sequencing of objectives. Next, the job aid and expert system were designed. An evaluation plan was developed to measure training validity. The designer identified strategies to ensure that transfer of training would occur. Finally, a review of existing materials was performed. Some video from a previously developed familiarization tape was identified as appropriate for the present training effort.

CHAPTER 4

DEVELOPMENT

Introduction

During the development phase, the designers see their hard work and patience transformed into a training product. This can be very exciting if the designers did their homework. During this phase the materials that are required to implement the training are produced and integrated into a comprehensive lesson. These materials must be carefully evaluated to reflect criteria identified in the design document.

The development phase began with the formulation of a plan. Steps required for training development were outlined. Next, the plan was executed. All materials were reviewed according to predetermined criteria. Finally, materials for the formative evaluation were produced.

Learning Activity Development Scheme

Based on the design document, media analysis, and identified training requirements the designers outlined a specific development plan. The plan described the necessary steps for training development, the specific materials each step produced, and the criteria used to evaluate the materials. These requirements are described separately, however, they were dependent upon each other and often occurred simultaneously. The steps were as follows:

Step 1: Graphics Development- Graphics of e-beam FRU's, components, and switch and potentiometer positions were produced

to be stored on the videodisc. These graphics helped illustrate procedures presented by the job aid and provide engineers with necessary concepts and discriminations for successful integration performance.

Step 2: Video Production- The first step in video production was the actual shooting of the video. Video included waveform profiles, components too complex to be graphically represented, and modeling of actual procedures by integration engineers. After the initial shoot, the video was reviewed according to specified criteria, described under Learning Activity Review. Next, the video was edited onto the master tape. The video was again reviewed to verify that editing was successful. Finally, the master tape was shipped to 3M for mastering. A video checkdisc was received and reviewed to verify that mastering was acceptable. A final disc was pressed after all video and graphic requirements were approved.

Step 3: IWPS Courseware Development- Due to the logistics of the IBM InfoWindows Presentation Systems, a courseware outline was developed prior to any programming. This outline described lesson flow and content requirements. Next, text-based menu pages were produced using the IWPS graphics capability. In accordance with the design, these menu pages presented macro level procedures. Additional procedure information was presented as ASCII text files by on-screen popup windows. These text files were developed using WordStar word processing software.

Step 4: Hardware/Software Integration- Upon receiving all IWPS hardware and software, the following components were identified

as present:

1. PS/2 Model 30
2. InfoWindow EGA card
3. GPIB Adapter card
4. EGA Jumper card
5. GPIB cable
6. InfoWindow Display
7. DOS 4.0 Operating System
8. InfoWindow Control Program
9. IWPS Interpreter Software
10. IWPS Editor Software
11. Sony LDP-1500 Videodisc player
12. Sony Adapter cable

At this point, the system was integrated and confirmed as fully functioning.

Step 5: Expert System Development- The expert system was developed using Prolog language. This step entailed the development of the design materials into executable code. The expert system was programmed and implemented on the InfoWindows system.

Step 6: Lesson Integration- This step entailed the integration of the hardware, software, and courseware materials. It unveiled the first viewing of the actual training product.

Step 7: Course Aids- The lesson was designed to automatically be presented once the hardware was turned on. A hardcopy description of simple troubleshooting procedures was developed to provide information if a problem were to occur during this process. In addition, a description of lesson elements useful to the end user was developed. This included the general lesson flow and program capabilities.

Step 8: Formative Evaluation Materials- Materials necessary for the one-on-one, small group, and field trial evaluations were developed.

Learning Activity Development

Videodisc graphics development occurred on the TrueVision Image Processing Software (TIPS) system. The graphic artist used hardcopy prints of FRU's and components as models. The graphics were developed to help the engineer locate FRU's, components, and switch and potentiometer positions. These graphics were edited onto the master tape, then pressed onto the videodisc. Although the graphics were evaluated and confirmed acceptable prior to pressing, the checkdisc graphics were difficult to read. This was a result of the anti-aliasing procedure used in bit mapped graphics; the small size of component labels; and the number of generations as a result of editing from the source tape onto the master tape, pressing onto the videodisc, and displaying the graphics on the IWPS monitor. Two solutions were employed to correct this problem. First, instead of presenting each component in its entirety, which resulted in cramming a lot of graphic information onto one screen, portions of the components were displayed. This allowed the text size to be increased and, therefore, easier to read. Also, a blue background was used instead of the original black background. As a result, the figure-ground perception of the graphics was more distinct and, therefore, easier to read.

As a result of Levie's media model, motion video was identified as a training requirement. Because of the unacceptable fidelity of graphically represented waveforms and the criticality of waveform identification to successful integration procedures, video was used. Unfortunately, the

configuration of the system available to the designers for shooting could not be modified to produce some crucial waveforms. This was flagged to management as a hindrance to meeting the goals of the training. It was determined that these waveforms would be shot at a later date. Once all of the video and graphics were produced, they were edited onto the industry standard one inch tape. During this process, the motto was "when in doubt include it on the master tape." Because the designers knew that there would be ample space on the videodisc, most video and graphics produced were included. It was important that all "alike" video and graphics be laid down in the same place during editing. This allowed the designers to easily find video and graphics on the videodisc and decreased access time of video frames during lesson play. An edit decision list was developed. This identified Society of Motion Picture and Television Engineers (SMPTE) timecode according to HRS:MINUTES:SECONDS:FRAMES. The timecode was converted into video frame numbers based on the National Television Standard Committee (NTSC) standard that normal video plays 30 frames per second. The conversion formula used was (FRAME #s) + (30 * SECONDS) + (60 * MINUTES). Once the tape was edited and approved, it was shipped to 3M for mastering. Upon receiving the checkdisc, it was reviewed, accepted, and ready to be integrated into the lesson.

Courseware development occurred on the IWPS system. This system is considered an authoring "environment" because it includes all the required hardware and software necessary for CAI development and implementation. Job aid lesson development began

with an ASCII lesson outline developed in WordStar. The outline included the events of the lesson and the following information per event:

1. Video play sequence (motion or still frame #, audio track, speed)
2. IWPS graphic (name, transparent color, wipe routine)
3. Literal text string (location, color)
4. Touch (location, acknowledgment type)
5. Sound (type)
6. Datahandling (variable settings, conditional statements)
7. Indicators (switch settings for additional lesson control and branching)
8. Miscellaneous (unconditional branching, external program hooks)

From this outline the lesson was programmed. An example of the programming code is presented in Appendix L. At this point, the IWPS graphic menus were developed. This occurred only after hardware and software incompatibility problems were solved. During the hardware/software integration the quotation "All that could go wrong, did!" applies. The software arrived prior to the hardware, which allowed the designers to begin lesson development using an IBM clone computer. Once the hardware was delivered, a number of problems occurred when the designers tried to verify that the system was fully functioning. After numerous communications with IBM technical support, it was determined that the software was significantly outdated. The version received

had since been updated approximately 50 times. The designers learned a valuable lesson of specifically identifying the software version number on purchase orders. There were also problems where the hardware did not support software capabilities and vice versa. The former situation occurred when the designers could not create high resolution 640 X 350 graphics, although documentation specifically identified this capability. It was determined that the Random Access Memory (RAM) of the PS/2 model was inadequate for this capability. Therefore, memory chips were installed. The latter situation of the software not supporting the hardware occurred when the processing speed of the computer was too quick and did not allow the software to perform necessary steps for closing crucial files. This resulted in a loss of data on two occasions. This problem was solved by exchanging the ten megahertz computer for one with a slower clockspeed of eight megahertz. Once these problems were solved, the designers were very impressed with the hardware and software capabilities of the IWPS.

The expert system was programmed using Prolog language. This is a declarative language which attempts to prove a goal as true based on rules and user supplied facts. This step required the programming of the knowledge base as well as the screen design for user input. The programming code is presented in Appendix M. All screens were text based and required yes or no responses from the end user. The expert system was designed as a diagnostic aid. After the materials were reviewed, it was determined that the expert system would be much more effective if

it was integrated with the videodisc. Since the diagnostic procedures required recognition of waveform criteria, presenting waveforms as video would be more effective than status quo text descriptions. This concept was presented to management as a future training enhancement.

After the courseware was developed and the IWPS system was verified as fully functioning, the entire job aid and expert system lesson was integrated. At this point, the lesson was reviewed according to the predetermined criteria outlined in the Learning Activity Review. The designers identified two problems with the job aid. First individual procedures were not easily referenced. It was very easy for the end user to become bogged down in the procedures. Also, the branching destinations were not clearly evident, which resulted in confusion when moving through the lesson. The solutions to these problems were to provide the user with the ability to return to the lesson menus from anywhere within the lesson. Also, the branching destinations were described at the bottom of each screen. Besides these problems, the lesson appeared to meet the predetermined criteria.

The course aid, displayed in Appendix N, presents a simple explanation of the initialization and operation of the InfoWindows system. This aid described normal start up procedures, how to move through the lesson, and how to properly exit. A block diagram of the InfoWindows system was also included. This was available if, for any reason, the system had to be moved and re-configured.

Finally, the materials for the formative evaluation were developed. These materials included the following:

1. Performance checklist: The task analysis served as the performance checklist. The checklist would be used during the formative evaluation to validate whether the tasks enabled the successful performance of each objective. This checklist would also be used during the summative evaluation.
2. Discrepancy report: This report was designed to identify problems with the step list, training module, job aid, videodisc or other. This report was used by the end user and provided a description of any problems encountered, recommended solutions, and resulting actions. The discrepancy report is displayed in Appendix O.
3. Reaction survey: This self-reporting survey was developed to measure step one of Kirkpatrick's evaluation model (1987). This survey, displayed in Appendix P, provided data concerning how well the training was received by the end user, whether it was easy to use, and how helpful it was in doing the job.

Learning Activity Review

The review of the lesson materials was performed by the designers, management, and SME's. Management and SME's verified technical accuracy of the materials at each review stage. The responsibility of the designers was to ensure the lesson represented the criteria outlined in the design document. The criteria by which the materials were evaluated are described below.

1. The videodisc graphics were reviewed in three stages: prior

to being edited onto the master tape, prior to being pressed onto the video checkdisc, and after the checkdisc was received. Specifically, they were reviewed for:

- technical accuracy
- readability
- visual quality

2. The video was also reviewed in three stages: prior to being edited onto the master tape, prior to being pressed onto the video checkdisc, and after the checkdisc was received. The criteria by which the video was evaluated included:

- visual quality
- technical accuracy
- lighting
- focus and sharpness
- adherence to video requirements

3. The IWPS menu pages and ASCII text files were reviewed for:

- technical accuracy
- spelling errors
- readability
- grammatical errors

4. The expert system was reviewed for:

- technical accuracy
- user-friendliness
- readability
- grammatical and spelling errors
- run-time efficiency

5. Once these materials were individually reviewed and accepted

they were integrated into a comprehensive lesson. The lesson was reviewed for user-friendliness, as well as the following content validity criteria:

- all content sufficiently covered the objectives
- all content reflected required standards and conditions defined per objectives
- lesson content, structure, topic, and length were in accordance with the design document
- lesson was self explanatory in usage
- cues and icons for moving through the lesson were easily recognizable
- procedures were easily referenced
- end users did not receive unnecessary information

Materials for Formative Evaluation Produced

Because only one IWPS system was available, those materials necessary to implement the training evaluation were limited to one final product. Of course, there were backups on floppy discs of the lesson courseware. This was done for documentation safety reasons. One video checkdisc was produced by 3M. A checkdisc allows the designers to make additional changes as a result of the formative evaluation. These necessary changes would be identified during the formative evaluation. Five performance checklists, course aids, reaction surveys, and discrepancy reports were produced for the formative evaluation. This supplied the designers and the students with a copy of course aid materials to be used during the formative evaluation.

Summary

The designers identified a learning activity development scheme based on the design document. This included the plans for personal computer and videodisc graphics development, video shooting and editing, expert system development, courseware development, hardware and software integration, and lesson integration. The actual development process and criteria used in evaluating the materials were described. The materials required for the evaluation phase were outlined.

CHAPTER 5

IMPLEMENTATION

Introduction

After the materials are formatively evaluated and modified, they must be prepared for implementation. This includes the reproduction of all materials as a marketable training product. Prior to implementation, it is important for the designers to gain the acceptance and enthusiasm of the supervisors and managers. If the supervisors and managers are enthusiastic, most often the end users will accept the training with the same excitement. If this is not achieved, the training may not be used and considerable time, effort, and money may be wasted. The materials required for training implementation were reproduced. Next, the actual implementation process was performed. Finally, data was collected from the summative evaluation. This data indicated training effectiveness.

Materials for Implementation Reproduced

During the development phase, a formative evaluation of the training was performed at Grumman GRO. During this phase, the training was tested on one-on-one and field trial groups representative of the target population. Information was collected which gave insight as to how the training could be improved. Corrections and revisions were performed based on these results. Finally, all materials required for final training implementation were produced.

Because only one IWPS system was available, those materials

necessary to implement the training were limited to one final product. Ten videodiscs were pressed. This was done because the cost of duplicate videodiscs, after the initial mastering, was fairly low. This provided additional videodisc copies if a disc was accidentally destroyed or lost, or IWPS systems were ordered in the future. The course aid explaining IWPS operations was produced once for the actual system and once for a backup copy. Five performance checklists were supplied to managers and supervisors. Forty reaction surveys and discrepancy reports were produced for implementation.

Instructional Delivery

During training implementation, the designers received important news. In addition to the present system being integrated, seven additional systems were originally scheduled for integration. However, this number had been cut to zero. This cut in integration was a result of problems encountered with previous systems delivered to IBM for manufacturing production, and the recent re-organization of the chip writing industry. Until the existing problems were identified and corrected, IBM decided to temporarily stop new integrations. Therefore, at the time of this writing the training was not implemented at Grumman GRO. However, during the first week of May 1990, the expert system and job aid were delivered as a formal training product to IBM, Fishkill. The training was implemented to both IBM and Grumman Technical Services. Grumman Technical Services supports IBM and the electron beam lithography program. The target population of both groups represented engineers and technicians.

The engineers were responsible for more difficult e-beam tasks, including testing and troubleshooting procedures. Technicians were responsible for general production operations. Their areas of responsibility were very different, however, both populations were familiar with beam bring up procedures and the EL-3+ system. Table 7 displays the participants' background and experience.

The target population used for implementation does not exactly represent the target population the training was originally designed for. However, the training requirements identified during the analysis phase were generally applicable in this setting. These elements included the problems statements, current and desired performance definitions, and the instructional goal and objectives.

During the implementation, the expert system and job aid were set up in close proximity to the actual equipment. All materials and equipment necessary for expert system and job aid set up were allocated. These materials included extension cords, electrical outlets, and power strips. A mobile cart was supplied to IBM and Grumman Technical Services. This allowed the engineers to move the expert system and job aid next to the actual components or FRU's with which they needed performance assistance. This was not as practical as first designed due to the limited space around the e-beam system. The actual equipment included rack elevations of FRU's, mainframe computers, and the beam column. If more than one engineer was working on the system at a time, the expert system and job aid were more of a performance hazard rather than enhancement. However, the

Table 7

Implementation Population Background

TITLE	SERVICE	AREA OF SPECIALTY	TRAINING*
	Grumman Technical Services		
Mechanical Engineer	3 yrs	Load/Unload	B
Electrical Engineer	1.5 yrs	Rework/Testing	C
Assistant Engineer	1 yr	Electronics	A
Electrical Technician	2 yrs	-	B, C
Electrical Technician	1.3 yrs	Electronics	C
Electrical Technician	1 yr	-	B, C
Electrical Assembler	4 mos	Rework	C
Assistant Engineer	9 mos	Mechanical Systems	C
Engineer	4 yrs	Systems	B, C
Electrical Technician	3 yrs	Electrical Appl.	A
Engineer	3.5 yrs	-	C
Engineer	1 yr	Electronics & Optics	C
-	3.5 yrs	-	C
Sr. Systems Analyst	3 yrs	Logistics	C
Engineer	4 yrs	Column	C
Project Engineer	12 yrs	Electro-Mech. Sys.	A
	IBM		
WSO	10 yrs	-	B, C
Sr. Auto. Equip. Spec.	4 yrs	All	A, B, C
Maintenance Engineer	1.5 yrs	-	C
Production Spec. WSO	1.5 yrs	Electronics	A, C
-	3.5 yrs	Column	A, C
Technical Equip. Spec.	3 yrs	Mechanical-CLS	C
Automated Equip. Spec.	3 yrs	Mechanical-Analog	A, B, C
Automated Equip. Spec.	6 yrs	Column, Logic, Analog	C
Sr. Engineer Lab Spec.	8 yrs	Hontas	C
Systems Analyst	15 yrs	Hontas	C
Staff Engineer	16 yrs	Digital/Overall Sys.	B, C

*Training types
A = formal education
B = classroom training by employer
C = On-the-job training

mobility of the expert system and job aid allowed the system to be moved to a place where it was not an obstacle.

The training product was designed as a turnkey system. Once the videodisc, computer, and monitor were turned on, all

initialization procedures were automatic. If a problem occurred during this process, the end user was referred to the course aid describing simple diagnostic procedures. Once the system was initialized, a menu was presented to the engineers. It provided the option of accessing the CAI/IVD job aid or the expert system. After an option was chosen, executed, and exited the menu options were presented again.

Although the expert system was originally designed to be implemented independent of the CAI/IVD job aid, the end user was provided the option of accessing the expert system from the CAI/IVD job aid. The combination of both types of training proved very effective concerning astigmatism procedures and diagnostics.

On May 10, 1990, after the training was set up for implementation, the designers presented 15 IBM and Grumman engineers and technicians with an overview of the expert system and job aid capabilities. An outline of the problems each type of training addressed was presented. This included a description of the conditions which were appropriate for expert system reference, and the conditions which were appropriate for CBT/IVD job aid reference. In addition, the designers provided a demonstration of the system features. Although the system was menu-driven and relatively easy to follow, the designers explained how to access information from the job aid. This included a demonstration of how to use the touch screen, the significance of task numbers displayed on each screen, and organization of the content. Next, the help feature capabilities

were presented. The designers demonstrated how to access the help feature and the type of graphic information available. Finally, start and exit procedures were demonstrated. It was emphasized that if start and exit procedures were incorrectly performed, damage may occur to the CAI system, and important information may be lost.

Next, the support materials were presented and described. These materials included the course aid, discrepancy reports, and performance checklists. The designers explained that the course aid would be located next to the system and provide basic operation and troubleshooting procedures for the system. Also, the set up diagram was presented. Situations which may require the system to be broken down and reconfigured were described. Precautions for doing either of these procedures were explained. In addition, the purpose of the discrepancy report was stated. This included directions for filling out the report, the type of necessary information, and to whom the report should be given.

During the presentation, it was equally important to gain the engineers' acceptance of the training. It was well known that some engineers viewed the expert system and job aid as a threat. It was obvious that the training replaced the eclectic knowledge some engineers worked years at attaining. The designers treated this issue very carefully by stressing that the expert system and job aid were tools to enhance their engineering skills However, their individual performances were very crucial to successful integration. Also, it was tactfully implied that the goal of the training was to improve their skills, not replace them.

After the staff was trained, it was important for the designers to gain the support and enthusiasm of supervisors and upper management. The designers were aware that management and supervisory attitude had a profound effect on the engineers' acceptance of the training. On May 16, 1990, the designers presented the goals and benefits of the training to approximately thirty supervisors and managers. The supervisors and managers represented both IBM and Grumman. Their responsibilities included electron beam system receiving and testing, production, operation, and maintenance. It was stressed that the purpose of the training was to make their jobs easier and more productive, not to take away responsibility. In addition, positive production outcomes that may result from the support and appropriate use of the expert system and job aid were presented. These outcomes included decreased equipment downtime, improved wafer quality, standardized procedures, and security of procedure knowledge. Similar to the engineering presentation, the designers demonstrated the expert system and job aid capabilities. At the end of the presentation, the supervisors and managers were encouraged to use the system and fill out the reaction surveys.

Data Collection

Summative evaluation is defined by Dick and Carey (1985) as "the design, collection, and interpretation of data and information for a given set of instruction for the purpose of determining the value or worth of that instruction." During this evaluation, data was collected from reaction surveys and

discrepancy reports. This data answered the question "Does the final training product assist in the integration of e-beam systems?" The responses from the reaction survey were very positive. Twenty-four out of 27 participants rated the training as better than expected or excellent. Eighteen out of 27 participants stated that the training will help them better perform their jobs. The discrepancy reports identified some problems with technical accuracy. Although the summative evaluation phase does not usually result in training modifications, discrepancy reports were analyzed and appropriate changes were made.

Summary

During this phase of instructional systems development, the training product was implemented in the final training environment. Although the final environment was different than originally defined, the instructional goal was appropriate for the desired training outcome. The instructional delivery strategies were outlined. A summative evaluation was performed. Data collected during the summative evaluation determined training effectiveness. The data collection process was described.

CHAPTER 6

EVALUATION

Introduction

Although the formative and summative evaluation phases are described together, they are distinctly different. Both types of evaluation are performed at different times in the ISD process, have different purposes, and yield different outcomes. Formative evaluation answers the question, "In what ways can the training be modified to be more effective?" The summative evaluation answers the question, "Does the training really work?"

A formative evaluation was performed with one-on-one and field trial groups. Due to management decisions small group evaluations were not implemented. Information was collected, and appropriate modifications to the training were completed. After training implementation, information was collected during the summative evaluation. Training effectiveness was determined.

Formative Evaluation

Formative evaluation is the process of collecting information concerning ways the training could be modified to be more efficient and effective. This evaluation was performed at Grumman GRO, during the development phase, and resulted in revisions to training materials. The three phases of formative evaluation include one-on-one, small group, and field trials. Prior to the formative evaluation, all materials were reviewed and approved by the designers, SME's, and management. The materials were then produced to be delivered to the target

population for which they were designed. These materials included one video checkdisc, one copy of the lesson software, five course aids, reaction surveys, discrepancy reports, and performance checklists.

One-on-One Trials

The goal of one-on-one evaluation was to identify obvious errors in instruction. This evaluation occurred throughout the development process, not as one evaluation stage. After the lesson materials were developed and approved by required personnel, they were integrated as lesson modules and formatively evaluated by individual engineers. The designers believed this would flag problems early and save a lot of effort later.

Prior to the one-on-one trials the engineers were briefed on the goals of the evaluation. It was explained to the engineers that performance discrepancies identified by the job aid and expert system were not a reflection of their individual skills. It was also explained that the job aid and expert system were prototype training tools and the steps presented were not 100 percent technically accurate. Also, the designers stated that they understood there were as many approaches to e-beam integration procedures as there were engineers. This put many of the engineers at ease and made them more relaxed during discussions. The engineers selected were those available at the time of the evaluation. Three engineers were used.

The designers' task of establishing rapport with the engineers was very easy. The engineers stated that they saw a great need for the training and were enthusiastic to be a part of

the evaluation. They also felt they were achieving personal gain by being exposed to the standardized procedures prior to other engineers.

During the evaluations, the designers sat directly next to each engineer so they could closely observe their reactions, comments, and enthusiasms. A performance checklist was used to verify technical accuracy of the steps. Unfortunately, a working system was not available for the designers to test the job aid and expert system against actual equipment. Again, the designers were limited to verifying the steps on paper only. During this evaluation the designers worked closely with the engineers, freely interacting with them and asking specific questions about areas of concern. The designers and the engineers went through the job aid and expert system together flagging both positive and negative aspects of the training. After the engineers reviewed the job aid and expert system, the reaction survey, discrepancy report, and course aid were evaluated but not completed. The following observations and comments were made concerning the expert system:

1. As identified by the designers during the needs assessment, the engineers were unfamiliar with astigmatism diagnostic procedures. It was obvious that simple verbal descriptions of some procedures were difficult for the engineers to understand.
2. The presentation of information was not clear. The engineers were required to perform two types of procedures during troubleshooting. The first type was

those procedures required to identify conditions of the system in order to determine appropriate corrective actions. The second type was the corrective actions themselves. These different types of procedures were not presented clearly by the expert system.

The first problem identified was difficult to solve. It appeared that some engineers did not have the prerequisite knowledge of astigmatism concepts and discriminations. It was agreed that the expert system would be greatly enhanced if it included graphics and video, similar to the concepts and discriminations presented in the job aid. The designers decided that instead of separate expert system and job aid modules for astigmatism procedures, one module which provided video and graphics for normal and diagnostic procedures was appropriate. This effort would require research concerning how InfoWindows and Prolog could be hooked together. The budgetary resources were not available at this time, but this was identified to management as a definite future training enhancement. However, the problem was alleviated in two ways. First, the procedures were re-written to be more descriptive and, therefore, easier to understand. Second, the students were given the option of exiting the expert system and entering directly into the job aid and vice versa. Although both types of training would be better served as one module, this solution was appropriate for the moment.

The second problem identified during one-on-one trials was much simpler to solve. The expert system screens were redesigned

to clearly present the two types of procedures required of astigmatism diagnostics. All steps which were necessary to determine system conditions were presented in yellow. However, all corrective actions were displayed under the heading "ENGINEERING ACTION."

The following observations and comments were made concerning the job aid:

1. Some components listed in the procedures were not graphically available during help sequences.
2. The help option, originally designed to be implemented by keyboard, was laborious to use.
3. Some of the language used was not typical to the engineers.
4. Typographical errors were identified.
5. Some of the procedures were not specific to the system configurations with which the engineers were currently working.
6. Technical accuracy of some steps was incorrect.

The following modifications were employed to correct these problems:

1. Components were added to help sequences.
2. The help option was designed as an icon in the upper left hand corner. By touching this icon the help option was accessed.
3. The language was modified to reflect language used by engineers in a typical setting.
4. Typographical errors were corrected.

5. Procedures were modified to reflect the specific configuration of the system with which the engineers were currently working.

6. Technical accuracy of identified steps was corrected.

Small Group Trials

The goal of small group trials was to verify modifications made during one-on-one trials and to identify additional problems. The small group trials were planned with eight engineers. Because the engineers available to the designers at GRO were limited to five, the designers planned to implement small group trials at IBM, Fishkill. The population identified at IBM for small group evaluations reflected the same characteristics as the GRO target population. However, at the last minute management denied the designers this opportunity. Their reasoning was that they did not want IBM personnel to view the job aid until it was completed as a formal training product. The management identified one-on-one and field trial groups as appropriate for formative evaluations.

Pilot Test

Pilot testing, also known as field trials, was planned as the final phase of formative evaluation. The goal of field trials was to identify additional problems not flagged during previous one-on-one trials and to verify modifications performed during the previous formative evaluation phase. First, the expert system and job aid performance objectives were measured according to a performance checklist. This was performed by an expert supervisor engineer. Although some steps could not be

verified against the actual equipment, they were logically measured as correct or incorrect based on the expert engineer's previous experience and knowledge. The step list was not provided in this document due to the sensitivity of the material. Each objective was categorized by the expert engineer according to the following:

A. The expert system or job aid did not provide assistance for meeting the objective.

B. The expert system or job aid provided inaccurate assistance for meeting the objective.

C. The expert system or job aid needed to provide additional information for meeting the objective.

D. The expert system or job aid provided correct assistance for meeting the objective.

As a result, the following expert system objectives were categorized:

D. 1. Given a system whose beam has been properly aligned and a computer-based expert system, the engineer will verify initial conditions for astigmatism procedures. Verification must include X-Y table and Spot Shape Monitor conditions.

C. 2. Given a system whose initial conditions have been verified and a computer-based expert system, the engineer will determine whether Stig 1 is on-axis or off-axis. This determination will be based on specific waveform criteria.

D. 3. Given a system where Stig 1 has been determined as

either on-axis or off-axis and a computer-based expert system, the engineer will perform Lens Supply adjustments. Adjustments will be based on specific waveform criteria.

B. 4. Given a system which has had required Lens Supply adjustments and a computer-based expert system, the engineer will perform Condenser Stig 1 adjustments. Adjustments will be based on specific waveform criteria, and whether Stig 1 is on-axis or off-axis.

In addition, the following job aid objectives were categorized:

D. 1. Given a system whose hardware has been properly assembled and a computer-based job aid, the engineer will verify the initial conditions for beam bring up procedures. Verification will include proper hardware installation, system power on, and yoke drivers off.

D. 2. Given a system whose initial conditions have been verified and a computer-based job aid, the engineer will power up and initialize the system. Power up and initialization must include turning on and setting up required FRU's and positioning of the X-Y table.

B,C: 3. Given a system which has been powered up and initialized and a computer-based job aid, the engineer will align the beam. Beam alignment must include first, second, third, and sample apertures.

A. 4. Given a system whose beam has been properly aligned and a computer-based job aid, the engineers will perform astigmatism adjustment procedures. Astigmatism

adjustments must include set up procedures and Lens Supply adjustments.

D. 5. Given a system which has had proper astigmatism adjustments and a computer-based job aid, the engineer will perform double deflection procedures. Double deflection procedures must include required Alignment Brightness FRU adjustments.

D. 6. Given a system which has had proper double deflection adjustments and a computer-based job aid, the engineer will perform shaping procedures. Shaping procedures must include the proper physical set up and required adjustments in the X and Y axis.

Of those objectives not successfully achieved, the tasks that had to be modified or added were identified and appropriately changed.

In addition, four engineers were asked to utilize the job aid and expert system as needed. This allowed the engineers to document any problems encountered during the expert system and job aid use. These discrepancy reports are presented in Appendix Q. Information collected included:

1. Report No. GR-F-1: a typographical error
2. Report No. GR-F-2: confusing tasks description
3. Report No. GR-F-3: technical accuracy problem
4. Report No. GR-F-4: suggestion for making the expert system more effective.

These problems were analyzed and resulted in the appropriate actions.

Summative Evaluation

The summative evaluation occurs after the development has been completed and the training has been implemented. Summative evaluation is measured according to the four stages of Kirkpatrick's model (1987). The four stages are:

1. Reaction- Were the participants pleased with the training, content, and materials?
2. Learning- Did the training facilitate learning of skills, techniques, and procedures?
3. Behavior- Was learning actually transferred to on-the-job performance?
4. Results- Did the training have any organizational effects?

The reaction and behavior phases of the summative evaluation were performed at IBM, Fishkill. Because learning was not a requirement of job aid performance, the learning phase was not measured. Similarly, because of the restricted schedule and budget, the results/impact phase was not evaluated as desired by the designers. This was due to management decisions and not under the control of the designers.

Reaction

The first stage of Kirkpatrick's evaluation measured reaction. A reaction survey was used to collect this information. The information collected included the ways in which the engineers liked and disliked the expert system, computer based job aid, and demonstration training module (Von Der Linn, 1990). The ratings included specific reactions to each

type of training and overall reactions to the tools as job performance aids. The reactions were very positive. Each question in the survey was analyzed according to a scale of one to five, where a rating of one indicated the best possible reaction. The results of this analysis are presented in Appendix R. Table 8 displays a summary of the reaction survey analysis.

Table 8

Summary of Reaction Survey Analysis*

	Expert System	Job Aid	General
survey questions:	C1A, C1B, C1C, C1D, C2, C3, C4	D1A, D1B, D1D, D1E, D1F, D2, D3	E1, E2, E3, E4, E5A, E5B, E5C, 35D, E5E, E6
IBM	2.38	2.01	2.1
Grumman	2.03	2.06	1.87
Both	2.18	2.04	1.91

*ratings represent average reaction of 27 surveys, based on scale of 1 - 5, where 1 rates as best possible reaction.

The comments received reflected both positive statements and constructive criticisms. The most frequent comment stated that the training was very easy to use, and the information presented was very helpful. This included the way in which graphic and video information was presented. It was also stated that these tools would be helpful for tasks that are often forgotten with time. Finally, there were a number of statements explaining that the job aid tools would be especially useful for a novice engineer or technician. Concerning constructive criticisms, it

was most often indicated that the technical accuracy of some steps was not exact. This reaction seemed common among engineers and technicians who worked on systems other than the EL-3+ system. A second common constructive criticism was the inability to exit from the job aid and expert system from any screen.

All results of the survey were disclosed to the Grumman Technical Services Electron Beam Lithography Project Engineer. At which time, he indicated that Grumman and IBM were enthusiastic about funding the next level of effort. This level of effort will include the investigation of all constructive criticisms and comments as a result of the reaction survey.

Learning

The second stage of Kirkpatrick's evaluation is learning. Because this project reflected a job aid, the measurement of learning was inappropriate. If learning was a requirement, the change of behavior according to predetermined criteria would be analyzed. The common types of data used in measuring learning include:

- Entry behavior scores
- Pretest scores
- Embedded test scores
- Post test scores

The two most common grading techniques for measuring learning are norm-referenced, also known as the relative grading system or criterion-referenced, also known as the fixed-percentage grading method. Norm-referenced techniques define grading criteria according to comparisons made to the performance

of other students. Criterion-referenced techniques define grades according to predetermined performance criteria. Prior to project turn on, a data analysis specification, outlined in Appendix S, was developed. If full, comprehensive training was a requirement, these analysis techniques would be employed.

Behavior

The third stage of Kirkpatrick's model, behavior, measured how well the expert system and job aid assisted the engineers in integration procedures. It was originally planned for the supervisors to evaluate the expert system and job aid according to a performance checklist. The goal of this evaluation was to verify the steps against an actual system. It was indicated by Grumman and IBM management that this evaluation plan would occur during the next level of effort. This was due to the budgetary ramifications as a result of using a system being prepared for, or presently being used for chip production, for the evaluation of this training product. Because IBM was not originally scheduled as the site for the summative evaluation and had not allotted budgets for such efforts, this evaluation would have to be postponed until the required approval was achieved. However, during this effort, the summative evaluation resulted in engineers documenting technical accuracy problems as they were identified during normal job aid use. Many of these problems were documented on the reaction survey, which were converted onto discrepancy reports by the designers. These discrepancy reports are presented in Appendix T. The following information was collected:

1. tasks number
2. problem description
3. suggested action
4. materials effected
5. action taken

Specifically, the following problems were documented:

1. Report No. I-S-1, I-S-3, I-S-6, I-S-7: problem description reflects confusing content, where information is not organized or explained clearly.
2. Report No. I-S-2, I-S-4, I-S-5, I-S-8: problem description reflects serious mistake, where information fails to teach required content.

These identified problems were analyzed, and appropriate actions were implemented.

Results/Impact

The final stage, results, measures organizational effects. Much to the designers displeasure, budget and scheduling did not allow for this evaluation stage. If results/impact were to be measured, the following data would be collected:

I. Time: Equipment downtime

1. Engineers not productive during downtime
   = salary/hour * hours
2. Engineers pulled from other efforts
   = salary/hour * hours
3. Overtime
   = salary/hour + $2.00 * hours

4. Efforts not related to production (research, re-design)
   = salary/hour * hours

II. Quality

1. Scrap, damaged equipment
   = costs of parts
2. Rework, system setup after hardware fix
   = salary/hours * hours
3. Rework, unacceptable wafer writes
   = salary/hours * hours

III. General costs in addition to normal operation

1. Overhead costs (maintenance and facilities costs)
   = costs
2. Operating costs (maintenance of class ten environment)
   = costs
3. Administrative costs
   (secretary, budget and schedule support, management)
   = costs

As shown, the data will include avoidable time, quality, and administrative/general costs. The costs of each category would be determined prior to training and at six month intervals after training. The data would be collected until there appeared to be a leveling off of costs and savings. A leveling of savings will occur because it is impossible to diminish all avoidable costs. The savings would be calculated based on the formula:

COSTS BEFORE TRAINING - COSTS AFTER TRAINING = SAVINGS

From these savings, the return on investment (ROI) would be calculated based on the formula:

$$\frac{\text{SAVINGS}}{\text{TRAINING COSTS}} = \text{ROI}$$

This return on investment calculation would identify to management the payback period. This means that within a certain amount of time after the training has been implemented, the original investment for training development would be "paid back" by cost savings as a result of training. At this point, all savings would be considered profit.

Learning Transfer

The transfer of training specifications were based on Broad (1982). Broad concluded from her research that measures of desired training results were often disappointing. The answer to improving results often concentrated on the improvement of the training itself. Instead, she indicated that more effort must be employed in gaining management support of transfer of training.

As a result, she compiled a list of 74 management actions that supported transfer of training to the job. These actions were categorized according to upper management involvement, training preparation, support during training, job linkage, and follow up training. These actions were rated by Human Resource Development specialists according to their observance of these actions in any organization and importance of these actions to training transfer.

Because this project does not reflect formal training, the basic premise of Broad's research does not truly apply. However, this does not mean that management and supervisory support was not needed. Many of the management support actions described in

Broad's research were appropriate and applicable. For example, the designers encouraged upper management to:

1. participate in advanced briefings of the training.
2. provide appropriate physical facilities for the training program.
3. meet with engineers to discuss ways to apply new behavior.
4. name appropriate personnel to training design committees.

During training preparation, management and supervisors were encouraged to:

1. actively participate in assessment of training needs.
2. actively participate in the development of objectives.
3. actively participate in the design of the training.
4. review instructional materials for technical accuracy.

Actions which supported training in progress, job linkage, and follow up training support were also encouraged. Management and supervisors were asked to:

1. participate in one or more training sessions.
2. practice ways to reinforce use of new job behaviors by engineers.
3. involve engineers in work-related decisions based on new learning.

As a result, the designers hoped that management and supervisory support and enthusiasm would positively effect the engineers' attitudes toward and acceptance of the job aid and expert system training.

Summary

Formative and summative evaluations were described. This description included measurement instruments used to collect data, procedures employed, and outcomes produced. The formative evaluation was performed at Grumman GRO. Information was collected as a result of one-on-one trials and pilot testing. Training was appropriately modified. The summative evaluation was conducted at IBM, Fishkill. This was changed from the original site at Grumman GRO. Despite this, the original instructional goal represented desired training outcomes. Finally, a plan for ensuring transfer of training was presented.

CHAPTER 7

SUMMARY AND RECOMMENDATIONS

Introduction

At this point, all phases of the ISD process have been exhausted. The result is a successful training product. Appropriate conclusions were drawn, reflecting what was learned from the project. Based on these conclusions, recommendations of how other instructional technologists may learn from the experiences of the designer were presented. Finally, a concluding statement describes the final thoughts of the designer.

Methods and Procedures Used

The original training setting illustrated by this project was Electron Beam Lithography Systems Integration, Grumman Great River Operations. However, implementation occurred at IBM, Fishkill. The summative evaluation was performed with Grumman Technical Services and IBM engineers and technicians. Although the original training requirements may not have exactly represented the final training outcomes, the instructional goal was identified as appropriate.

During January 1989, Grumman Simulation/Trainer Products was approached by IBM and Great River Operations with a list of e-beam lithography tasks to be trained. Due to the large number of tasks involved with the original task list, the beam bring up procedures were selected as the tasks to be trained. This determination was based on the criticality of these tasks to

e-beam integration. The instructional systems development model was used for the analysis, design, development, implementation, and evaluation of the training. This approach represents a systematic process which produces training via an iterative process. This process resulted in training efficiency and effectiveness.

During the analysis phase, job information was collected which helped focus training needs and desired outcomes. As a result of current and desired performance definitions, status quo performance deficiencies were identified. Performance deficiencies were a result of the lack of standardized e-beam performance and criteria, the specialized engineering roles and responsibilities, and inadequate diagnostic knowledge and skills. Based on job performance variables and learner aptitude factors, it was determined that a job aid and expert system, not comprehensive training, was necessary to meet training needs. The training presented two types of e-beam procedures, normal integration procedures and diagnostic procedures. Normal integration procedures were presented by a CBT/IVD system, whereas; diagnostic procedures were presented by an expert system.

Next, a terminal instructional goal was formulated. The criteria for defining the goal was based on Dick and Carey (1985). The terminal instructional goal was categorized according to the intellectual domain of learning, as described by Gagne (1987). Next, all tasks, skills, and knowledge required for successful goal performance were identified in successive

order of execution. The tasks, skills, and knowledge were categorized according to learning outcome levels described by Merrill (1987). These tasks were converted into instructional objectives, according to Mager (1984). Each objective identified the conditions, action, and criteria required for successful performance of beam bring up procedures.

Next, the expert system and job aid were designed. The design reflected perceptual issues presented by Fleming and Levie (1978). The output of this phase was the CBT/IVD storyboards and expert system flow chart, decision tree, matrix, rule base, and screen design. These materials were reviewed according to predetermined criteria. Once these materials were individually approved, they were integrated into a training product. The expert system and job aid were formatively evaluated during one-on-one group and pilot testing trials. Required modifications were implemented. At this point, the materials were reproduced to reflect a marketable training product.

Next, the training was implemented. The designers demonstrated the expert system and job aid capabilities to the engineers, technicians, supervisors, and managers. Finally, the training was summatively evaluated according to Kirkpatrick's (1987) reaction and behavior phases.

Conclusions

If the following conclusions sound pessimistic, they are not meant to be. The designer believes that the best conclusions are those from which learning results. Because learning reflects a change in behavior, beliefs, or knowledge, the conclusions drawn

from this project describe how the designer might do things differently in the future. The conclusions are based on the development of "first of a kind training." This project included many "firsts": a new hardware and software delivery system with which the designers had never worked, content area which was dynamic, large, and unfamiliar to the designers, and a technology which was fairly new to the e-beam industry and lacked performance standards.

The first conclusion drawn by the designers identified the lack of budget and scheduling resources planned for the IWPS procurement, integration, and familiarization tasks. The designers were not prepared to confront the many software and hardware integration tasks required to begin CBT development. Instead, the project was budgeted and scheduled as a training development project, which assumes these tasks are performed prior to training development. This problem was first encountered during the analysis phase. The designers were overwhelmed with unavoidable procurement problems, hardware incompatibilities, and incorrect software versions. As a result, the designers found themselves fulfilling the role of liaison between vendors, the customer, and Grumman more often than the role of instructional technologists. In addition, the designers were surprised at the amount of technical support needed to get the IWPS authoring environment fully functioning. This resulted in an unplanned internal engineering effort and many hours on the phone with the IBM technical support hotline.

Similarly, the design phase did not schedule the time

necessary for the designers to gain a full working knowledge of IWPS capabilities. After the design phase was completed and development began, the designers gained insightful knowledge about IWPS capabilities. This was especially true after the designers discovered that the software version they had originally received was antiquated. After finally receiving the most current IWPS software version, many new and improved capabilities had to be re-learned. Although the designers were excited about the added capabilities, many modules had to be re-designed to reflect the new abilities.

A second conclusion drawn by the designers was the importance of making decisions concerning content requirements prior to training development. This was especially true considering the large scope of the content, dynamic nature of the tasks, and lack of standardized procedures. From the beginning, the designers found themselves overwhelmed with a huge amount of content. Originally, the training was to include eleven areas of responsibility within beam bring up procedures. However, the designers quickly recognized that this was overly ambitious. Instead, the designers agreed that delivering approximately half of this scope in a more comprehensive manner was more important than training all eleven areas in a low level of detail. It was also concluded that because the technology was fairly new, it was necessary to identify the final point when no new task modifications would be considered. This was decided after the designers became extremely frustrated with the large number of modifications being identified during training development.

Initially, the designers tried to update the expert system and job aid as changes were identified. However, they recognized that it was necessary to stop training modifications or the project might never be completed.

The reason for the large number of training modifications was the dynamic nature of the tasks and lack of procedure standards. Originally, the designers did not recognize that there were as many approaches to e-beam procedures as there were engineers. As a result, the designers received new and different information from the subject matter experts, which was not necessarily incorrect. After the designers recognized that this may be a problem, the designers themselves determined what performance standards the expert system and job aid would reflect, based on input from SME's.

Recommendations

As a result of the conclusions drawn, the designers recommend two different approaches to developing first-of-a-kind training. The first approach is to include in the contract the required budget and schedule for system procurement, integration, and familiarization tasks. The second approach is to dedicate IRAD (internal research and development) budget to system integration and content familiarization prior to contract turn on.

Both approaches must be carefully analyzed. The former solution may be less desirable to the customer. Customers may be unwilling to pay for system orientation procedures especially if such knowledge may be applied in future, unrelated training

development. Their attitude may be "Why should we pay for efforts other customers may not have to?" However, the latter solution may not be feasible. First, there is a possibility that IRAD budgets may not be available. Second, the amount of forewarning a trainer receives prior to contract turn on often leaves no time for such efforts. However, it is important to recognize that if these factors are considered prior to contract turn on, training development will be more efficient. This will result in minimal interruption from non-scheduled business, and time and effort will be dedicated to scheduled training tasks only.

A second recommendation, based on the previous conclusions, is for the designers to become subject matter experts in the training content. This allows the designers to make important decisions concerning the training size and scope, baselines which define completed training stages, and appropriate training standards. In addition, designers will be equipped to ask intelligent and applicable questions and gain important information from SME's.

Concluding Statement

As with the culmination of most projects, the designer found herself reminiscing, "If only I knew then what I know now." Of course, hindsight is always 20/20. However, every project is a new learning experience. As I faced new dilemmas, dealt with frustrating problems, and experienced positive results during this project, I also gained insightful knowledge which allowed my skills to grow professionally as well as personally.

In all honesty, when this project was completed, delivered, and overwhelmingly approved, I found myself unhappy with the end results -- wishing I could begin again this time doing everything correct. I knew if I had a second chance I could make this training flawless. After all, I had lived, breathed, and dreamed this project for the past 16 months. I only wanted what anyone else would want in my position, to be proud of my efforts. Instead, I focused too sharply on each tiny flaw of the project. At this point, I also realized that I was much too close to this project and did not view it as objectively as others did. Instead, I reminded myself of the positive comments I had heard: "There is truly a need for this training. I wish this was around when I was performing e-beam procedures." "Thank you. This makes my job that much easier." "I can even perform beam bring up procedures with this, and I don't even work here." Finally, I stepped back and viewed this project through the eyes of those around me. I too was duly impressed, and very proud of my efforts.

APPENDIX A

Needs Analysis

NEEDS ANALYSIS

DATE: 2/89

TITLE OF JOB: Systems Integration Engineer

I. Performance Discrepancy

A. Identified problems:

- o unacceptable wafer quality
- o re-work of unacceptable wafers
- o down time of e-beam device
- o overtime hours
- o turnover

B. Current performance:

Current performance reflects very specialized knowledge of e-beam integration and testing procedures. This results in integration problems when key personnel are not available. Inadequate performance standards exist. This is a result of no written procedure documentation and no formal training programs.

C. Desired performance:

- o decrease in specialized knowledge of e-beam integration and testing procedures
- o standardized e-beam integration and testing procedures
- o decrease in device downtime
- o increase in wafer quality

D. Target audience:

Audience includes approximately 10 engineers, age range from 25-60. All have experience with electron beam lithography. Many have experience specific to current generation of e-

beam device, EL-3+. Some have experience on-site at IBM, Fishkill, as technical support personnel. Length of service ranges from 2-10 years.

E. Turnover rate:

Approximately one engineer per year leaves the company. Leave of absence is often temporary. Temporary leave of absence occurs when an engineer is assigned a position on-site at IBM, Fishkill. Temporary assignment may be up to two years. For each person who leaves the company (permanent or temporary) one person is hired for replacement.

II. Training or non-training solutions

A. Do job incumbents know the duties and standards required for the job? Depends. Because of the specialization of engineers, most are proficient in some areas and not in others. However, there is a lack of standards required of the job.

B. Do job incumbents and supervisors agree on the duties and standards required for the job? No. Incumbents and supervisors have different approaches to same procedures. Various approaches may yield similar outcomes.

C. Are engineers capable of learning the job duties and tasks? Yes. Engineers have either experience and/or formal education in content area. Engineers have physical and mental potential to perform required procedures, yet are not over-qualified for the job.

D. Have engineers performed desired job duties in the past?

Yes, in their area of specialty. This is not true outside each engineer's area of specialty.

E. Is the skill used often? Depends. Some skills are performed often (as in daily readiness checks) others are performed rarely. Because this is a prototype system, some skills have never been performed.

F. Is non-performance rewarding? There are few reinforcers for non-performance. Positives for desired performance include limited overtime hours, free holidays, promotions, verbal reinforcement from management, monetary increases in salary, promotions.

G. Are there obstacles in performing as desired? Few obstacles are present. However, there may be problems if raw materials and equipment are not available as needed. Also, because this is a prototype procedure, there may be some equipment/procedural problems that cannot be anticipated. In general, there is the appropriate authority, time, tools, and resources for desired performance.

H. What are possible training constraints?

- Time available for instruction is subject to e-beam delivery schedule.
- If CBT/IVD is the appropriate medium, no equipment exists.
- There may be limited space for CBT/IVD equipment in laboratory area.
- No training program, or procedure documentation

exists.

- o Training is required for limited number of EL-3+ device integrations. However, training development is in preliminary stages and device integration occurs rapidly. For each device the training is not available for future integrations there is a decrease in ROI.
- o Because technology is fairly new, procedures may change as technology matures.

III. Recommendations

The goal of training is to improve performance of e-beam procedures for Systems Integration Engineers. This will decrease tool downtime and integration costs. There may be a simpler solution than comprehensive training. Due to the criticality of procedures, the large number of procedures, and the frequency of task performance, a job aid is recommended. The suggested medium for the job aid is a CAI/IVD system. The CAI/IVD system should be used in close proximity to the actual equipment. This recommendation must be verified as a result of a comprehensive media analysis.

APPENDIX B

Criticality, Complexity, and Frequency Rating of Tasks

	CRITICALITY	COMPLEXITY	FREQUENCY
1.0 Initial conditions	3	3	1
2.0 Power up system	3	3	1
3.0 Beam alignment	5	5	2
4.0 Adjust astigmatism	4	4	2
5.0 Adjust servos	3	2	1
6.0 Shaping	4	3	2
Average rating	3.6	3.3	1.5

* Rated on a scale of 1 - 5, low to high respectively

APPENDIX C

Job Analysis

JOB ANALYSIS

JOB TITLE: Systems Integration Engineer

I. Mechanical Engineer

A. **Writing a test wafer**

operate wafer * handler
type software commands
evaluate test wafer

B. **Preparing for write**

operate * table
operate *
assemble ITA
disassemble ITA

II. Digital Engineer

A. **Performing clip level determination procedure**

B. **Performing beam bring up**

align 1, 2, 3 apertures
get beam profile
check * cup

C. **Performing Beam Feedback**

III. Analog Engineer

A. **Performing * calibration**

Prepare physical setup
Zero the offsets

B. **Performing * calibration**

Prepare the physical setup
Perform * calibration

C. **Aligning ***

align on line *
align off line *

IV. Column Engineer

A. **Preparing column**

bring beam down
set up *

set up *
set up * corrections
focus *
write wafer

B. **Diagnosing Problems**

inspect image quality
diagnose charging problems
diagnose * problems
diagnose * problems

C. **Maintaining Column**

clean column

* component names and procedures intentionally deleted due to sensitivity of material

APPENDIX D

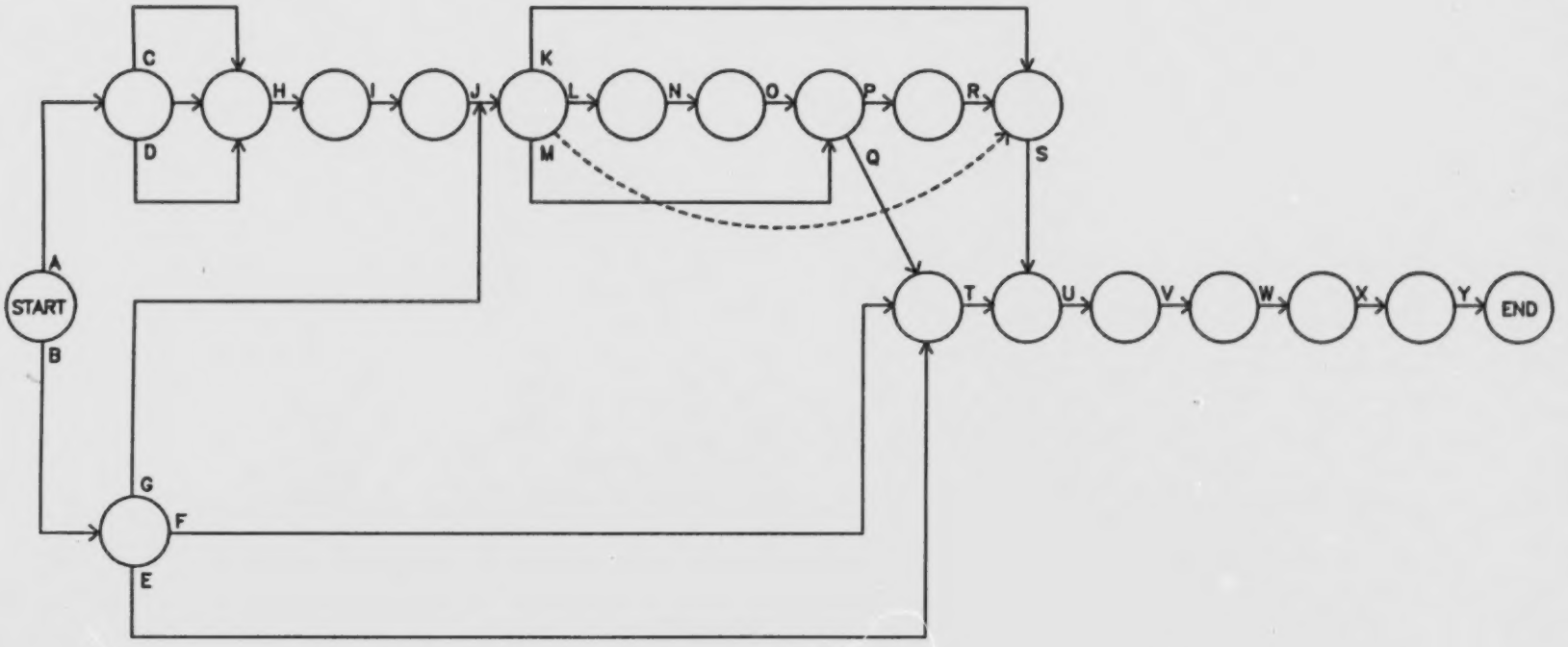
Project Planning

PERT CHART IMMEDIATE PREDECESSORS- EL-3+

	DESCRIPTION	IP	T	ES	EF	LS	LF	S
A	needs analysis	-	3	0	3	0	3	0
B	learner analysis	-	1	0	1	9	10	9
C	training require.	A	1.5	3	4.5	3.5	5	5
D	media analysis	A	2	3	5	3	5	0
E	hardware design/procur.	B	1	1	2	37.5	38.5	36.5
F	software design/procur.	B	1	1	2	37.5	38.5	36.5
G	VHS tape at GRO	B	1	1	2	10	11	9
H	task analysis	C,D	2.5	5	7.5	5	7.5	0
I	performance obj.	H	2	7.5	9.5	7.5	9.5	0
J	storyboarding	I	1.5	9.5	11	9.5	11	0
K	branching/lesson flow	J	1	11	12	16.5	17.5	5.5
L	video shot sheets	J	1	11	12	11	12	0
M	graphics development	J	3	11	14	13.5	16.5	2.5
N	video shooting	L	1	12	13	12	13	0
O	video editing	N,M	3.5	13	16.5	13	16.5	0
P	edit decision list	O	1	16.5	17.5	16.5	17.5	0
Q	disc mastering	O	1.5	16.5	18	37	38.5	20.5
R	IWPS outline	J,P,K	2	17.5	19.5	17.5	19.5	0
S	lesson authoring	R	19	19.5	38.5	19.5	38.5	0
T	system integration	E,F,Q	3	18	21	35.5	38.5	17.5
U	lesson integration/debug	T,S	9	38.5	47.5	38.5	47.5	0
V	delivery at GRO	U	1	47.5	48.5	47.5	48.5	0
W	formative evaluation	V	3	48.5	51.5	48.5	51.5	0
X	revision	W	4	51.5	55.5	51.5	55.5	0
Y	final delivery	X	1	55.5	56.5	55.5	56.5	0

T = Estimated time of event (weeks)
ES = Earliest Start (weeks)
EF = Earliest Finish (weeks)
LS = Latest Start (weeks)
LF = Latest Finish (weeks)
S = Slack time (weeks)

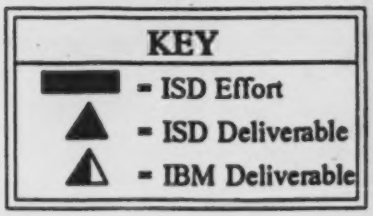
CRITICAL PATH = A,D,H,I,J,L,N,O,P,R,S,U,V,W,X,Y
Projected finish = 56.5 weeks

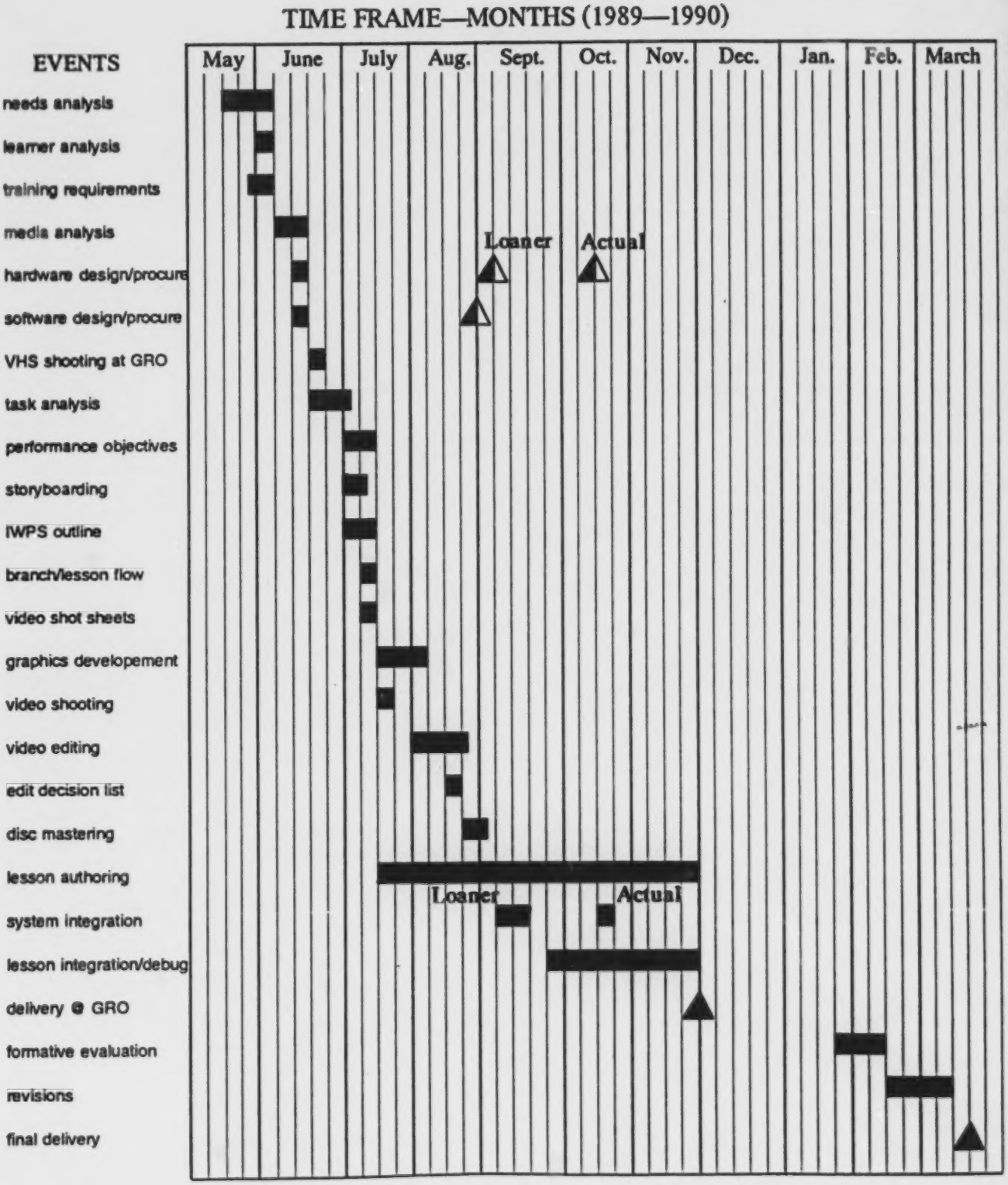


123

124

GANTT CHART—EL 3+





APPENDIX E

Design Document

DESIGN DOCUMENT AND SPECIFICATION

FOR IBM EL-3+ JOB AID

GRUMMAN SIMULATION/TRAINER PRODUCTS
INSTRUCTIONAL SYSTEMS DEVELOPMENT
JUNE 1989

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1.0 INTRODUCTION

1.1 Information Sources

Information gathered for this design document was extracted from meetings held between Grumman Simulation/Trainer Products, Grumman Great River Operations, and IBM personnel.

Various formal and informal meetings were held among Grumman S/TP and GRO to determine requirements and provisions of training job aid. On 2/16/89, proposal DTP-BUSOPS-M-89-005 was submitted to required personnel, in response to an IBM request for information. The proposal included the following:

1. Ground Rules and Assumptions/Statement of Work
2. Task Descriptions and Estimates
3. Schedule

Since the training proposal deliverance, requirements have been refined. This design document will reflect latest modifications and provisions.

1.2 Overview

The Electron Beam Lithography Devices were designed by IBM, with manufacturing and integration of the EL-3 systems performed by Grumman Great River Operations. The third generation of the Electron Beam imaging techniques became operational in the early 1980s.

The current generation of the electron beam imaging technique, the EL-3+, has greatly improved wafer writing time, increased data per chip, as well as decrease in chip and wafer size. The EL-3 device has deleted the time consuming masking step based on its direct write capability. In comparison to optical writing techniques of the past, electron beam projection is advantageous in that it results in more precise measures and correct pattern positions on wafers.

IBM has agreed to a preliminary training assignment, which will result in a prototype job aid system for part of the EL-3+ procedure. The job aid will be used to verify the technical accuracy of the procedures, and as the criterion specification for the training prototype to be developed soon after job aid delivery. The task delegated by IBM is known as the Beam Bring Up.

1.3 Purpose

The purpose of this design document is to present a plan for developing a computer based/interactive videodisc job aid for the Electron Beam Lithography 3 Plus device utilized by IBM, whose system integration is performed by Grumman Great River

Operations. The written products resulting from the ISD process, will be documented in this design document for the following purposes:

- Provide management with information needed to evaluate the course design and allow commencement of design and development phases.
- Serve as the "master plan" for courseware developers, programmers, the SMEs in the development of the job aid.
- As a reference document for subsequent courseware developers, programmers, and SME's who were not involved in the original development process. For the purpose of learning about the rationale and process used in the job aid design and development.

1.4 Personnel

CBT/IVD development is an inter-team disciplinary approach. No one person has all the knowledge and skills to complete this project alone. At the time of this writing the following personnel were inclusive in the job aid effort:

Winston Thaw: Grumman Operations, Program Director of the Electron Beam Lithography operation. General overseer of the job aid project.

Bob Kane: Grumman, Great River Operations, Subject Matter Expert, available for technical information collection and verification.

Ken Cresser: Grumman, Great River Operations, Subject Matter Expert who will be primary contact with Courseware Development Team for technical information collection and verification.

Jim Becker: Grumman, Display/Trainer Products, Program Manager responsible for general supervision of project and budgeting and scheduling of Courseware Development job aid deliverables.

Bob Von Der Linn: Grumman, Display/Trainer Products, Courseware Development team member directly responsible for design and development of job aid deliverables.

Kimberly Stevenson: Grumman, Display/Trainer Products, Courseware Development team member directly responsible for design and development of job aid deliverables.

Bill Frank: Grumman, Display/Trainer Products, Computer Generated Graphic Artist.

Kerry Adams: Grumman, Display/Trainer Products, Computer Generated Graphic Artist.

2.0 PROBLEM IDENTIFICATION/NEEDS ASSESSMENT

2.1 Needs Assessment

In the past, integration and diagnostic procedures on the Electron Beam Lithography have been performed by a limited number of highly specialized personnel and have been taught via on-the-job training. The implementation of CBT/IVD media will positively effect the following "problems" to be considered:

1. EL-3+ Maintenance Engineers must spare crucial time for OJT duties, resulting in less time available for actual EL-3+ operations.

2. OJT rarely ensures standardization of maintenance procedures.

3. Lack of assurance for future knowledge availability as qualified engineers terminate from company.

4. The increased role specialization of EL-3+ integration team, limiting in that the unavailability of key personnel, will crucially effect operation and integration of the device.

As well as:

5. The job aid will serve as the only existing documentation available. It may be used as a reference for future device upgrades, as well as present device configurations and procedures.

6. Enhancement of the EL-3+ as a marketable product.

7. The criticality of the integration maintenance procedures and assurance of qualified, experienced, competent personnel in the operation and maintenance of the EL-3+ device.

2.2 Present Performance

At this time, there are no formal job aids in existence for integration and maintenance procedure assistance and diagnostics. Diagnostics are performed by the few specialized personnel who have the required knowledge to do so. When spare time is available, procedures are informally taught on the job with actual equipment, by qualified personnel.

2.3 Desired Performance

The job aid delivery method for EL-3+ procedures will be computer based, and utilize individualized, and interactive strategies. When an engineer needs assistance, they will be given the option to refer to the job aid, located near the actual device. The engineer will access the required procedures by interacting freely with the menu driven system. As a result, there will be a standardized, accurate, and reliable information delivery system available for engineering assistance. This will increase the quantity and quality of competent personnel.

2.4 Target Population

The target population includes engineers who have operated the existing EL-3 device. They do have some knowledge of EL-3+ theory and skills necessary for EL-3+ operation. All users have highly technical backgrounds, and physical science experience. The target population is motivated in performing proper procedures.

3.0 APPROACH/STRATEGIES

3.1 Course Breakdown

INTENTIONALLY DELETED

3.2 Development Phases

The development of the job aid for the EL-3+ system will be done in three phases:

3.2.1 Analysis of Job Aid Procedure Requirements

A comprehensive analysis of specified tasks will be performed by S/TP with validation from Great River Operations SMEs. As a result, a task listing of all steps required to perform procedures will be developed to include criteria needed to evaluate acceptable performance of steps, the sequence in which the procedures are performed, and conditions under which procedures are performed.

3.3.2 Design and Production

Non-deliverable working documents will be created during the design phase which will include storyboards, scripts, video shot lists, artwork and sketches, narration scripts, and edit decision lists. These documents will become the basis of all production outputs. Production includes video shoots, artwork and graphics generation, software development, professional narration, video editing, and videodisc pressing by 3M.

3.3.3 Implementation and Evaluation

Upon receipt of a video "check disc" from 3M, integration of the hardware and courseware will take place. "Debugging" of the job aid program by Grumman personnel will occur in order to locate any errors in the job aid system. These problems will be modified and corrected prior to the lesson being delivered. After on-site delivery to GRO, a critical evaluation by S/TP and GRO personnel will occur, to ensure accuracy and completeness before final production of courseware. At the end of on-site evaluation, changes within the scope of the original statement of work will be

implemented, prior to final job aid delivery. It is conceivable that further evaluation will continue after final delivery, to verify long term job aid outcomes.

3.4 Assumptions

Information obtained from meetings and data collection resulted in the following conclusions and assumptions:

1. Basic Hardware and software configuration and requirements will include: IBM InfoWindow authoring environment, IBM PS/2 Model 30 computer, IWPS authoring system and editor, and Sony LDP-1500 Videodisc player. It has been agreed that one system will be delivered to S/TP, and later transferred to Great River Operations as a delivery system.

2. Job aid requirements will not inhibit the development and delivery of the actual EL-3+ device, or operations at the IBM Fishkill plant. Therefore, all videotaping, data collection, and SME conferencing must be done on either an overtime basis or at the convenience of those involved.

3. The job-aid will be a level III system, meaning the videodisc player is interfaced to an external computer and/or other peripheral processing devices.

4. There is no existing formal curriculum.

3.5 Schedule

The job aid schedule is contingent upon many stipulations. Because the EL-3+ system integration is still in the design and development stages, it is not definite what procedures will be included in the job aid. Therefore, the FEA and video shooting are dependent upon these limitations. As required procedures become known, even if out of actual procedural succession, analysis and design of these procedures will commence. This will result in a very non-sequential, modular FEA procedure, which will later be integrated and modified to form start-to-finish Beam Bring Up procedures.

The goal of the job aid is to assist in the system integrations of future EL-3+ devices. The more time that passes between job aid delivery and actual device delivery, the less effective the job aid becomes in the assistance of future system integrations. Therefore, it is necessary to understand the schedule within the context of the device delivery.

3.6 Course Aides

A course aide will be delivered with system to provide

direction for lesson execution. To be included are the following directions:

- Hardware turn on instructions
- Lesson initiation instructions
- User control options and inputs, what they mean and how they are used (touch locations, keyboard inputs)
- Simple system malfunctions and corrections

4.0 GOAL STATEMENTS

The general goal of this project is to encompass as much information as possible within the scheduled timeframe, with as great a quality as possible. This goal must be met without hindering the delivery of the device. As implausible as this may sound, it is conceivable. It will be necessary to find a balance between all these factors, which will result in an efficient and effective job aid.

4.1 Management

Upon completion of this CAI/IVD job aid program, the courseware development group will have successfully:

- o met scheduled deadlines.
- o completed project within budget requirements.
- o developed high quality, effective training.

4.2 Project

Upon completion of this CAI/IVD job aid program, the project will successfully reflect:

- o technical accuracy.
- o reduced maintenance costs.
- o decreased production of bad wafers.
- o diminished downtime.

4.3 Learner

Upon completion of the CAI/IVD job aid program, the student will demonstrate:

- o fluent comprehension of necessary EL-3+ procedures and principles.
- o knowledge of powering up the device from a "cold" state, called Beam Bring Up procedure.
- o understanding of the criticality of proper procedures and safety principles.

5.0 CONSTRAINTS

5.1 Equipment

No IBM InfoWindows system exists at S/TP or GRO sites. Therefore, new hardware must be procured. Lab space and support equipment (electrical sockets, desks, extension cords) must be made available for development system located at S/TP, and job aid system at GRO.

5.2 Software

Software requirements include IWPS configuration, courseware code, and CMI software. Procurement budgets must be allotted.

5.3 Coordination

Coordination between hardware and software procurement is being handled via the IBM regional marketing representative. Instruction (formal if available) of IWPS capabilities for Instructional Developers and Programmers is necessary, and must be considered in scheduling and budget requirements. IBM Technical support is available through telephone contact with qualified personnel.

6.0 DELIVERABLES

6.1 Working documents

1. 5 final copies of design document
2. 5 final copies of course script/storyboards
3. 5 final copies of task analysis
4. 1 copy of check-videodiscs
5. Artwork and sketches
6. Video shot lists
7. Edit decision lists
8. 5 copies of consolidated software
9. 10 copies of final-pressed videodiscs
10. 5 copies of operator/instructor course manuals

6.2 Hardware/Software deliverables for development and job aid system requirements:

1. PS/2 Model 30, # 8530-021
2. InfoWindow EGA card, # 5240
3. GPIB Adapter card, #1503
4. EGA Jumper Card, # 6583
5. GPIB cable, # 5040
6. InfoWindow Display, # 4055-001
7. Dos 4.0 Operating System, # 6280256
8. InfoWindow Control Program (V1.3), # 587-BBB FC8392
9. IWPS Interpreter Software, # 6024505
10. IWPS Editor Software, # 6024504
11. Sony LDP-1500 Videodisc player
12. Sony Adapter Cable

7.0 COURSE CONTENT DESCRIPTION

7.1 Overview

At the time of this writing the lesson to be developed is the Beam Bring-Up procedures. This lesson is critical in terms of the importance of the procedure, as well as the ramifications of this prototype job aid for evaluating S/TP's training ability.

This procedure is the process by which a maintenance engineer "turns on" the device from the power off state.

7.2 Conditions

The conditions under which this procedure is performed includes the following:

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7.3 Objectives

Provided with the required hardware, software, and courseware configuration for the EL-3+ job aid, the user will have access to data concerning the following diagnostic tasks inclusive in the Beam Bring-Up procedure:

INTENTIONALLY DELETED

8.0 REFERENCES

1. Engineering memo DTP-ENG-M-89-031, 5/9/89
2. Business Operations Training Proposal memo DTP-BUSOPS-M-89005, 2/16/89
3. Memo- Hardware and Software Requirements, 5/10/89
4. Groved, T.R., Pfeiffer, H.C., Newman, T.H., Hohn, F.J. EL3 system for quarter-micron electron beam lithography, J. Vac. Sci. Technology. B 6 (6), Nov/Dec 1988, pp 2028-2032.

APPENDIX F

Job Aid Storyboarding Examples

PROJECT: _____ DATE _____ MODULE _____ EVENT _____

PROGRAMMING NOTES:

ABEKAS #: _____ CHYRON #: _____

Graphic Title: _____ Disk: _____

SOURCE SMPTE: ___:___:___:__ DURATION: ___:___:___

MASTER SMPTE: ___:___:___:__ DURATION: ___:___:___

NARRATION ☐ CH.1 ☐ CH.2

SOURCE SMPTE: ___:___:___:___ DURATION: ___:___:___

COMPUTER OVERLAY

VIDEO

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SUBFIELD MATCH ENTER

133

143

144

PROJECT: IBM EL-3 #27 DATE Nov 89 MODULE _____ EVENT _____

PROGRAMMING NOTES: OSCILLOSCOPE

ABEKAS #:_____ CHYRON #:_____

Graphic Title:_____ Disk:_____

SOURCE SMPTE:____:____:____:__ DURATION:____:____:____

MASTER SMPTE:____:____:____:__ DURATION:____:____:____

NARRATION ☐ CH.1 ☐ CH.2

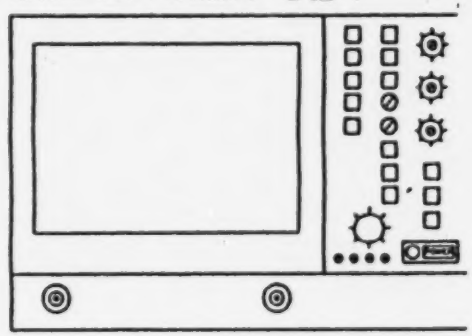
SOURCE SMPTE:____:____:____:____ DURATION:____:____:____

COMPUTER OVERLAY

145

VIDEO

1 2 3 4 5 6 7 8 9 10 11 12 13 14



146

PROJECT: IBM EL3 DATE _____ MODULE _____ EVENT _____

PROGRAMMING NOTES: ALIGNMENT BRIGHTNESS ETC (SERVO SWITCHES)

ABEKAS #: _____ CHYRON #: _____

Graphic Title: IBM 1A Disk: _____

SOURCE SMPTE: ____:____:____:__ DURATION: ____:____:____

MASTER SMPTE: ____:____:____:__ DURATION: ____:____:____

NARRATION ☐ CH.1 ☐ CH.2

SOURCE SMPTE: ____:____:____:____ DURATION: ____:____:____

COMPUTER OVERLAY

147

VIDEO

148

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135

PROJECT: IBM E4-B

DATE _____ MODULE _____ EVENT _____

PROGRAMMING NOTES: BEAM COLUMN

NARRATION ☐ CH.1 ☐ CH.2

ABEKAS #: _____ CHYRON #: _____

Graphic Title: BM 6 6A (↑ without type) Disk: _____

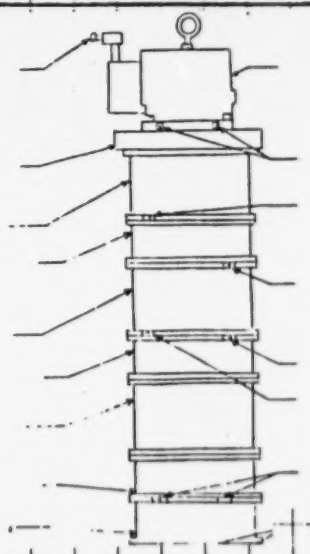
SOURCE SMPTE: ___:___:___:__ DURATION: ___:___:___

MASTER SMPTE: ___:___:___:__ DURATION: ___:___:___

SOURCE SMPTE: ___:___:___:___ DURATION: ___:___:___

COMPUTER OVERLAY

VIDEO



1 2 3 4 5 6 7 8 9 10 11 12 13 14

PROJECT: IBM/EBC DATE MODULE EVENT

PROGRAMMING NOTES:

ABEKAS #: CHYRON #:

Graphic Title: IBM12 Disk:

SOURCE SMPTE: : : : DURATION: : : :

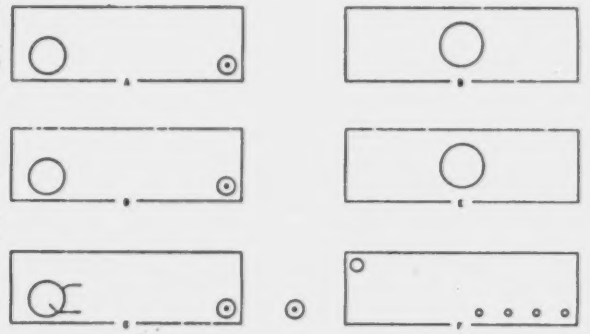
MASTER SMPTE: : : : DURATION: : : :

NARRATION ☐ CH.1 ☐ CH.2

SOURCE SMPTE: : : : DURATION: : : :

COMPUTER OVERLAY

VIDEO



1 2 3 4 5 6 7 8 9 10 11 12 13 14

137

PROJECT: IBM EL-3 #27

DATE Nov. 89 MODULE _____ EVENT _____

PROGRAMMING NOTES: ALIGNMENT BRIGHTNESS FRU

FRAMES: 6817-6820

ABEKAS #: _____ CHYRON #: _____

Graphic Title: IBM 1B Disk: _____

SOURCE SMPTE: ___:___:___:__ DURATION: ___:___:___

MASTER SMPTE: ___:07:47:06 DURATION: ___:00:04

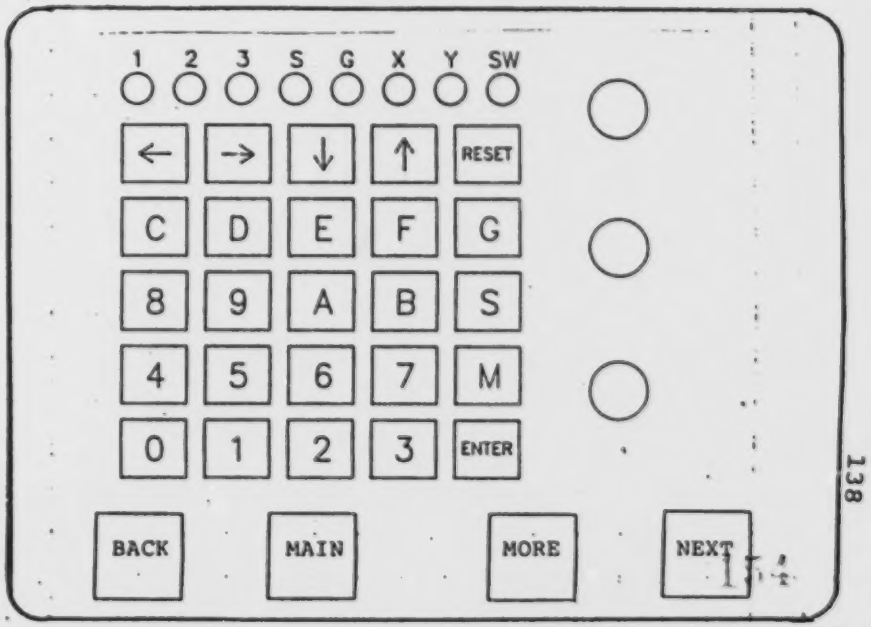
NARRATION ☐ CH.1 ☐ CH.2

SOURCE SMPTE: ___:___:___:___ DURATION: ___:___:___

COMPUTER OVERLAY

153

VIDEO



138

PROJECT: _____ DATE _____ MODULE _____ EVENT _____

PROGRAMMING NOTES:

ABEKAS #: _____ CHYRON #: _____

Graphic Title: _____ Disk: _____

SOURCE SMPTE: ___:___:___:__ DURATION: ___:___:___

MASTER SMPTE: ___:___:___:__ DURATION: ___:___:___

NARRATION ☐ CH.1 ☐ CH.2

SOURCE SMPTE: ___:___:___:___ DURATION: ___:___:___

COMPUTER OVERLAY

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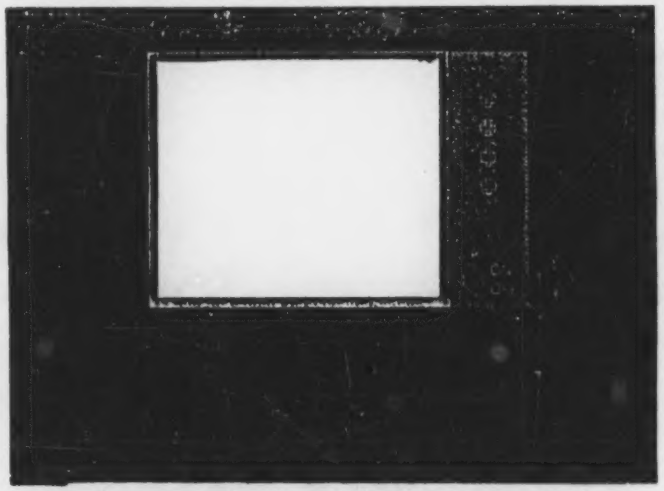

139

PROJECT: IBM EC-3 DATE MODULE ENT

PROGRAMMING NOTES:

ABEKAS #:_____ CHYRON #:_____

Graphic Title:_____ Disk:_____

SOURCE SMPTE:___:___:___:__ DURATION:___:___:___

MASTER SMPTE:___:___:___:__ DURATION:___:___:___

NARRATION ☐ CH.1 ☐ CH.2

SOURCE SMPTE:___:___:___:___ DURATION:___:___:___

COMPUTER OVERLAY

VIDEO

1 2 3 4 5 6 7 8 9 10 11 12 13 14

140

PROJECT: LISA1 EC-3

DATE _____ MODULE _____ EVENT _____

PROGRAMMING NOTES:

ABEKAS #: _____ CHYRON #: _____

Graphic Title: IBM13 Disk: _____

SOURCE SMPTE: ___:___:___:__ DURATION: ___:___:___

MASTER SMPTE: ___:___:___:__ DURATION: ___:___:___

NARRATION ☐ CH.1 ☐ CH.2

SOURCE SMPTE: ___:___:___:___ DURATION: ___:___:___

COMPUTER OVERLAY

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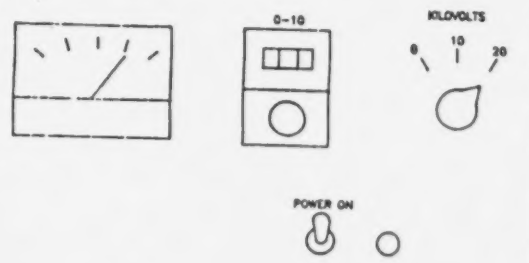
VIDEO



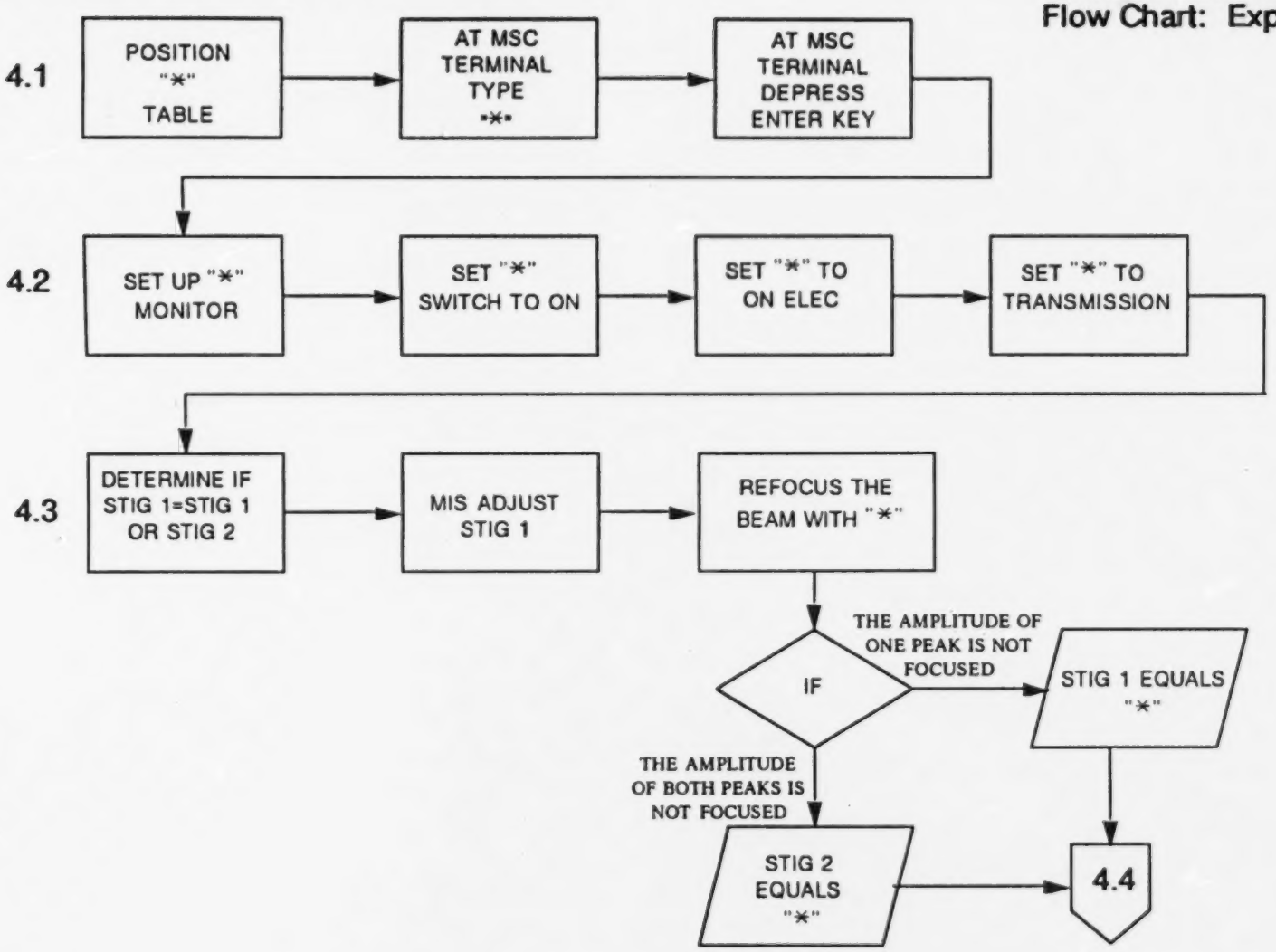
141

APPENDIX G

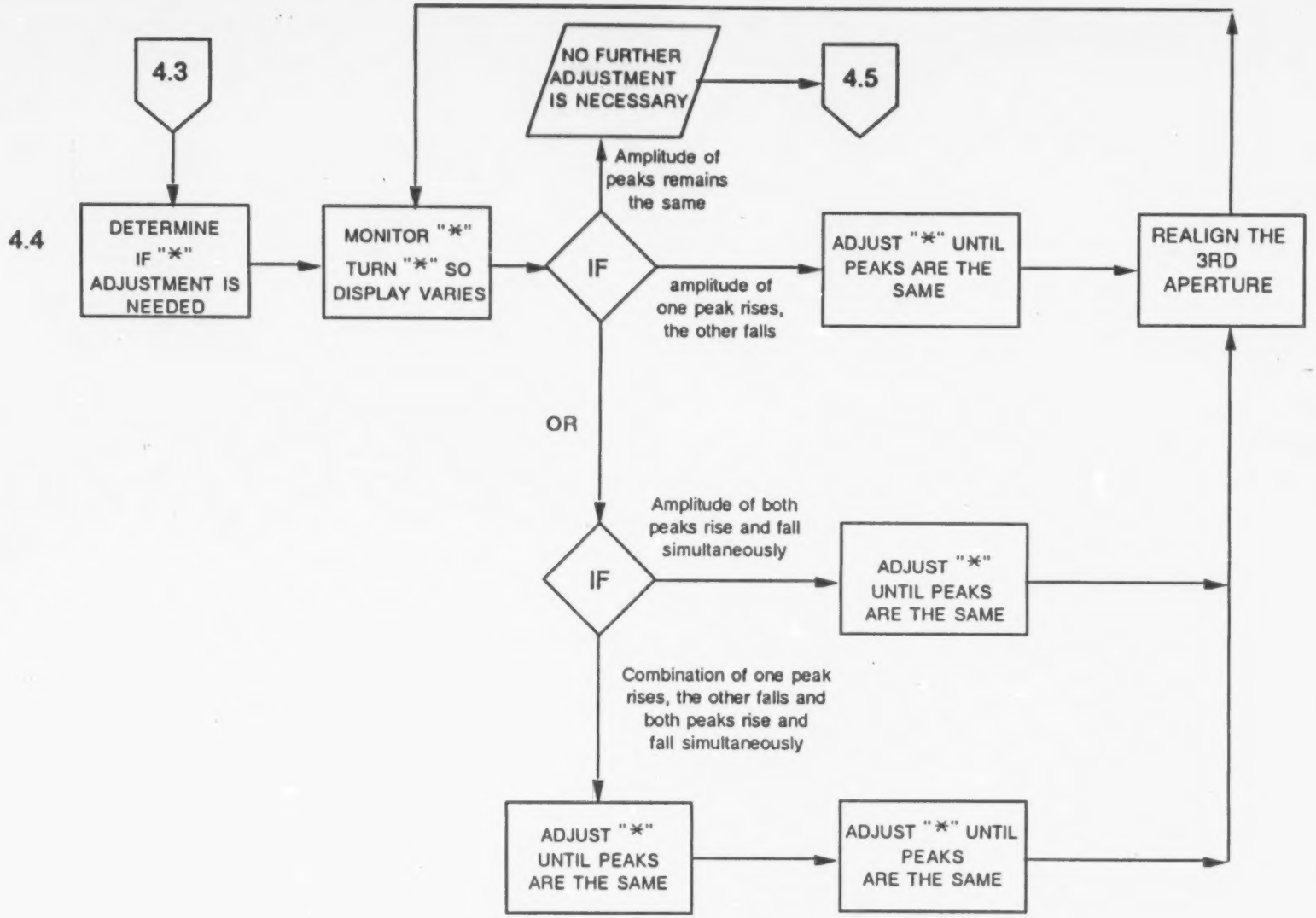
Expert System Flow Chart

ADJUST ASTIGMATISM

Module 4.0
Electron Beam Lithography
Flow Chart: Expert System

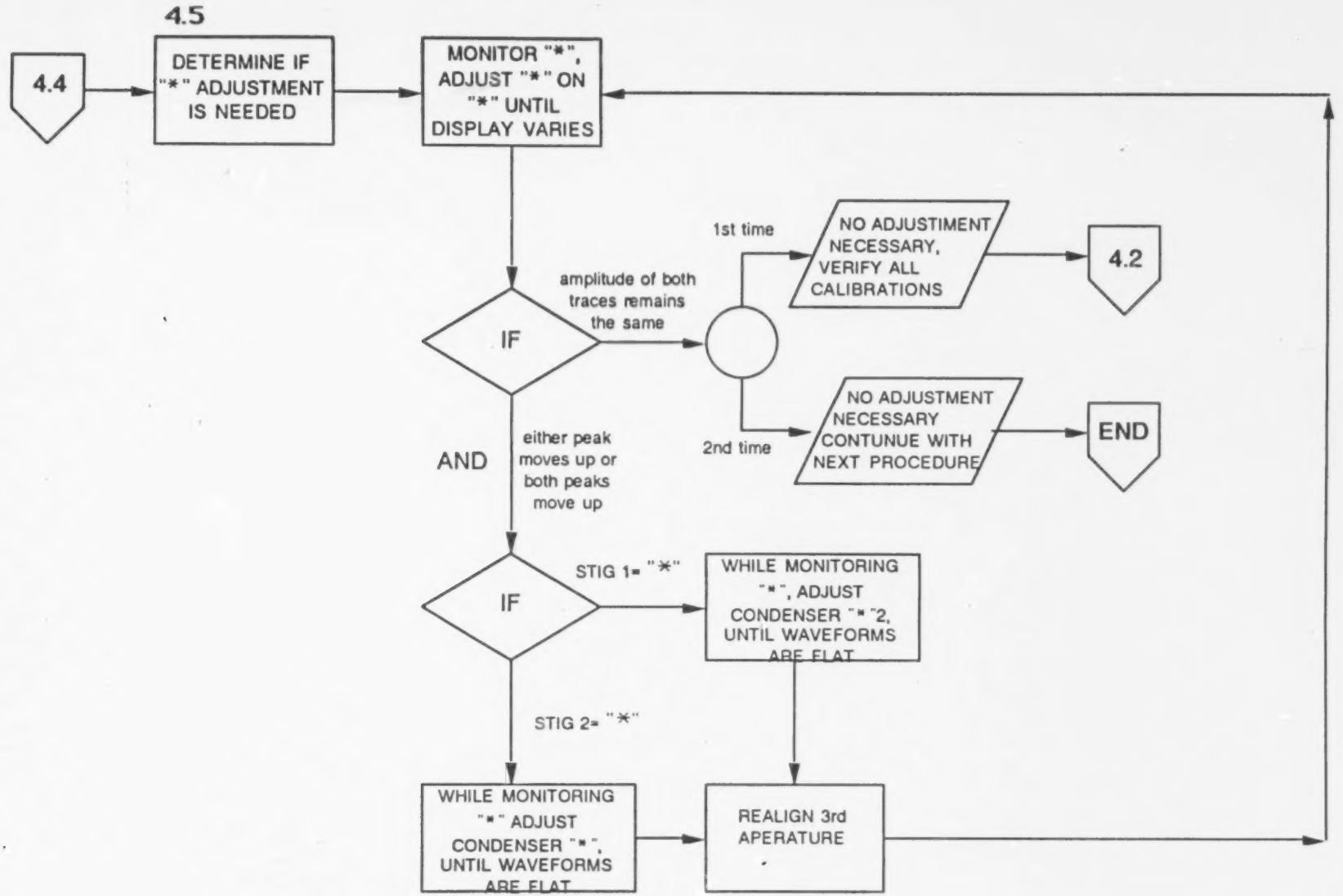

4.1
POSITION "*" TABLE
AT MSC TERMINAL TYPE "*"
AT MSC TERMINAL DEPRESS ENTER KEY
4.2
SET UP "*" MONITOR
SET "*" SWITCH TO ON
SET "*" TO ON ELEC
SET "*" TO TRANSMISSION
4.3
DETERMINE IF STIG 1=STIG 1 OR STIG 2
MIS ADJUST STIG 1
REFOCUS THE BEAM WITH "*"
IF
THE AMPLITUDE OF ONE PEAK IS NOT FOCUSED
STIG 1 EQUALS "*"
THE AMPLITUDE OF BOTH PEAKS IS NOT FOCUSED
STIG 2 EQUALS "*"
4.4

"*" Procedures intentionally deleted due to sensitivity of material


4.3
NO FURTHER ADJUSTMENT IS NECESSARY
4.5
Amplitude of peaks remains the same
4.4
DETERMINE IF "*" ADJUSTMENT IS NEEDED
MONITOR "*" TURN "*" SO DISPLAY VARIES
IF
amplitude of one peak rises, the other falls
ADJUST "*" UNTIL PEAKS ARE THE SAME
REALIGN THE 3RD APERTURE
OR
Amplitude of both peaks rise and fall simultaneously
IF
ADJUST "*" UNTIL PEAKS ARE THE SAME
Combination of one peak rises, the other falls and both peaks rise and fall simultaneously
ADJUST "*" UNTIL PEAKS ARE THE SAME
ADJUST "*" UNTIL PEAKS ARE THE SAME

"*" Procedures intentionally deleted due to sensitivity of material

144


4.5
4.4
DETERMINE IF "*" ADJUSTMENT IS NEEDED
MONITOR "*", ADJUST "*" ON "*" UNTIL DISPLAY VARIES
IF
amplitude of both traces remains the same
1st time
NO ADJUSTIMENT NECESSARY, VERIFY ALL CALIBRATIONS
4.2
2nd time
NO ADJUSTMENT NECESSARY CONTUNUE WITH NEXT PROCEDURE
END
AND
either peak moves up or both peaks move up
IF
STIG 1= "*"
WHILE MONITORING "*", ADJUST CONDENSER "*"2, UNTIL WAVEFORMS ARE FLAT
STIG 2= "*"
WHILE MONITORING "*" ADJUST CONDENSER "*", UNTIL WAVEFORMS ARE FLAT
REALIGN 3rd APERATURE

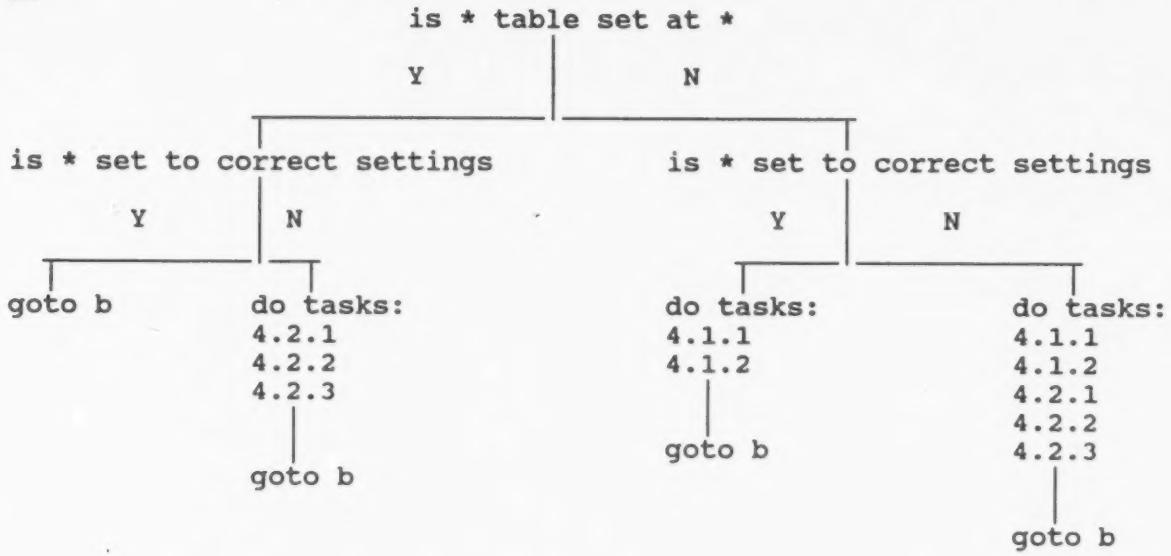
"*" Procedures intentionally deleted due to sensitivity of material

APPENDIX H

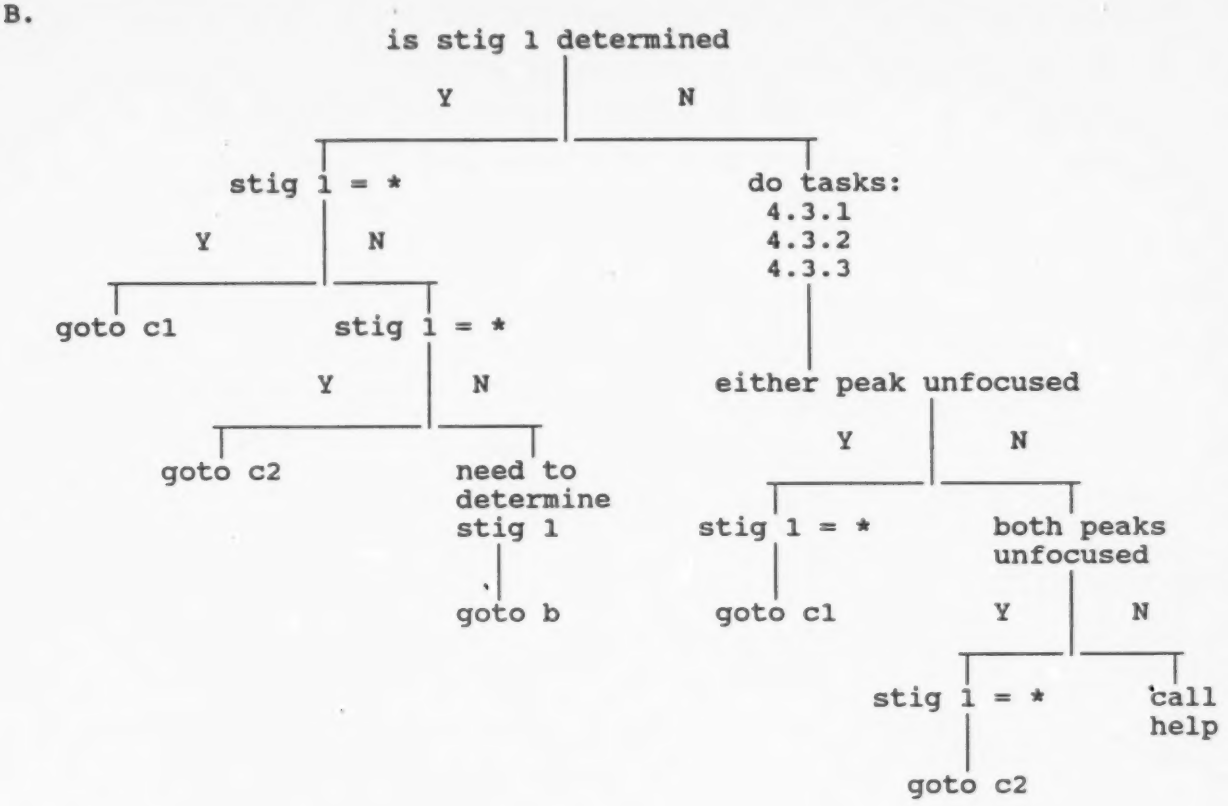
Expert System Decision Tree

DECISION TREE

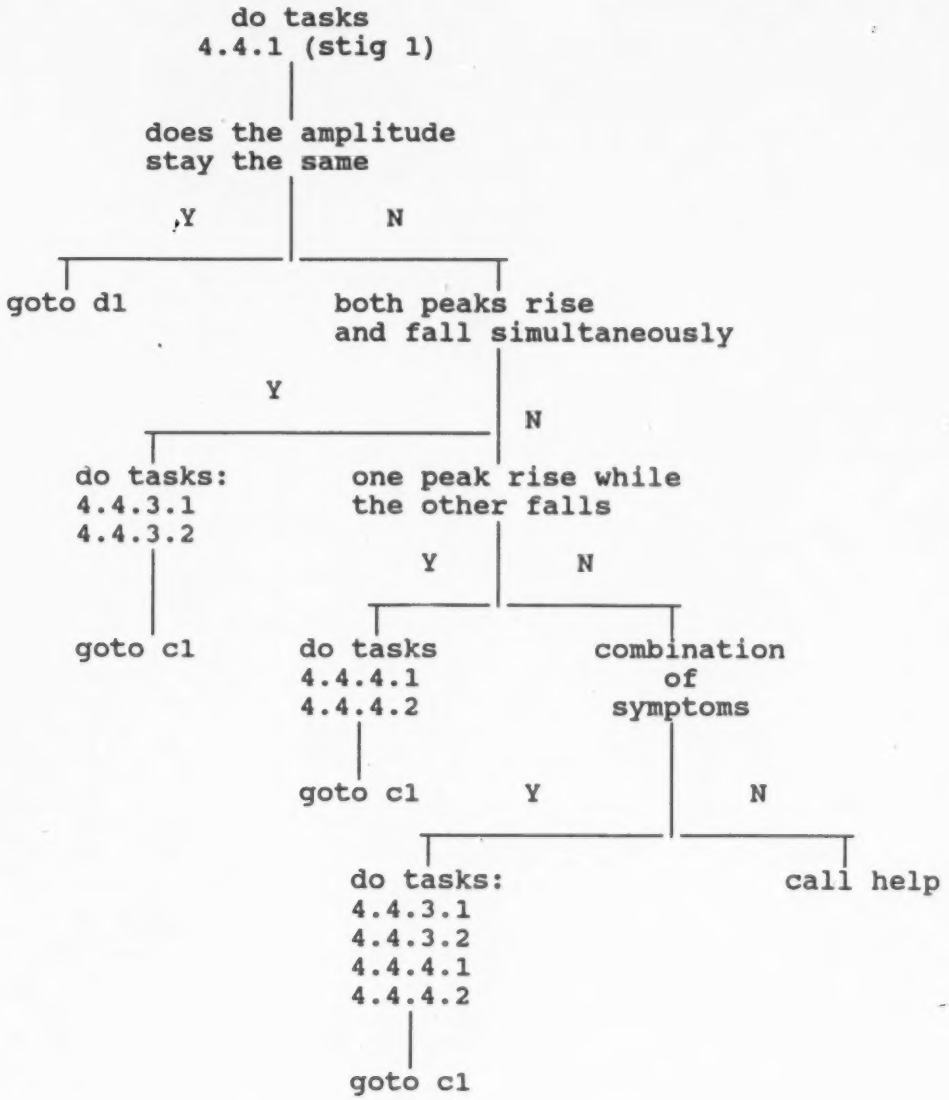
A.



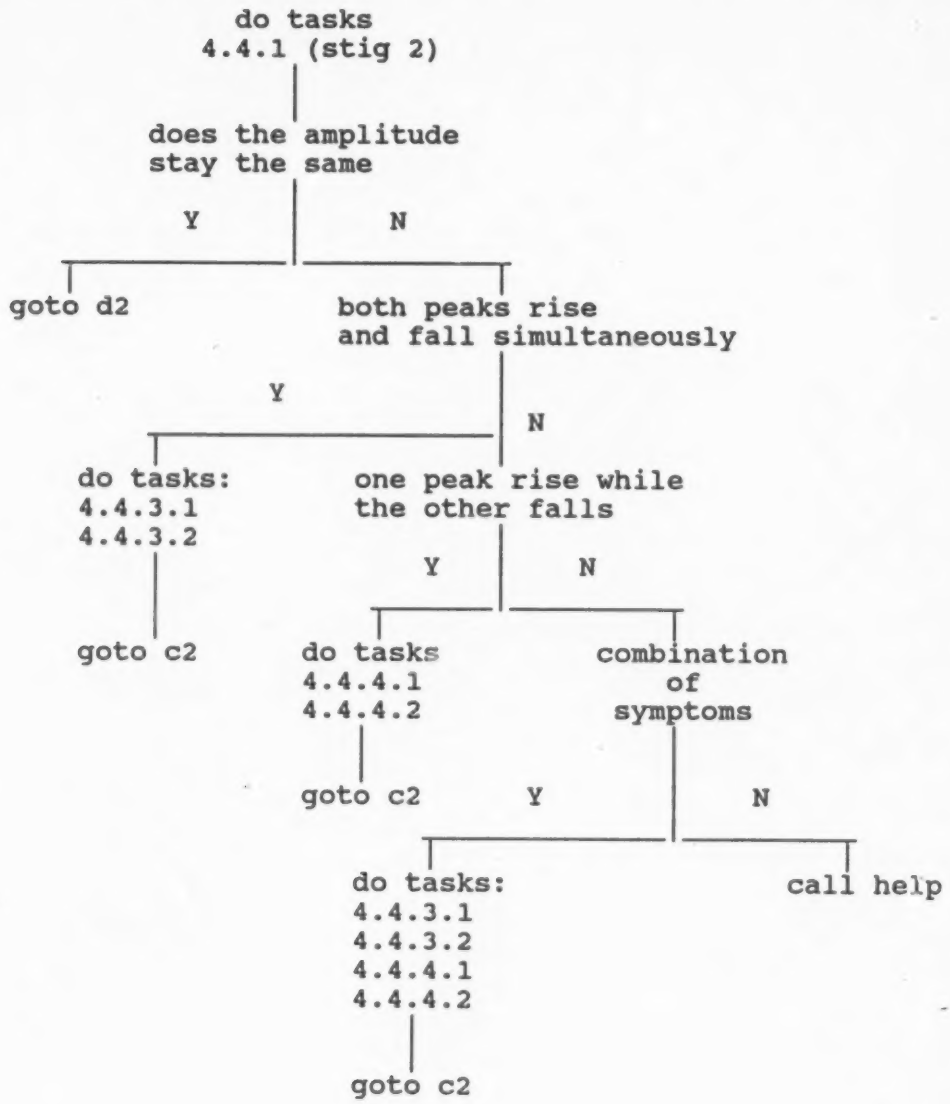
B.


is stig 1 determined
Y
N
stig 1 = *
do tasks:
4.3.1
4.3.2
4.3.3
Y
N
goto c1
stig 1 = *
either peak unfocused
Y
N
Y
N
goto c2
need to determine stig 1
stig 1 = *
both peaks unfocused
goto b
goto c1
Y
N
stig 1 = *
call help
goto c2

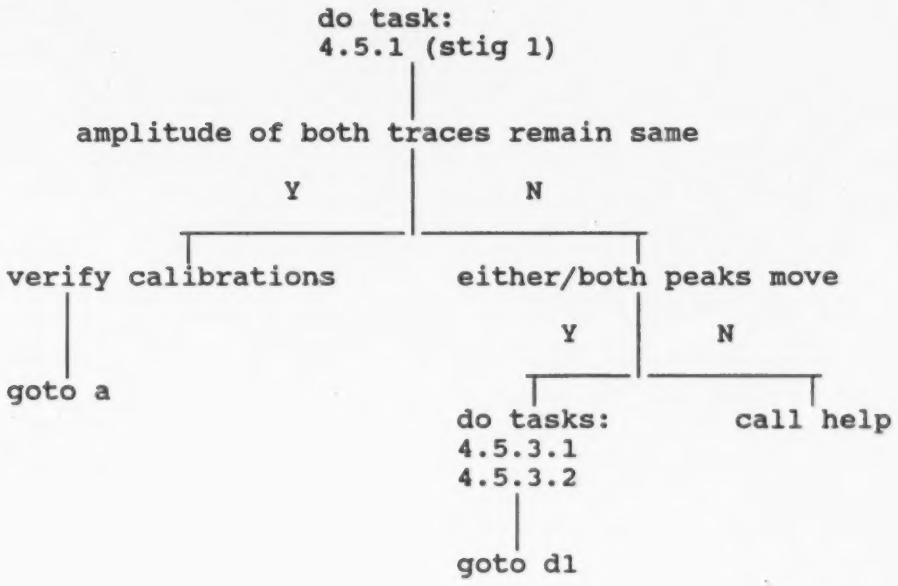
C1.


do tasks
4.4.1 (stig 1)
does the amplitude
stay the same
Y
N
goto d1
both peaks rise
and fall simultaneously
Y
N
do tasks:
4.4.3.1
4.4.3.2
one peak rise while
the other falls
goto c1
Y
N
do tasks
4.4.4.1
4.4.4.2
combination
of
symptoms
goto c1
Y
N
do tasks:
4.4.3.1
4.4.3.2
4.4.4.1
4.4.4.2
call help
goto c1

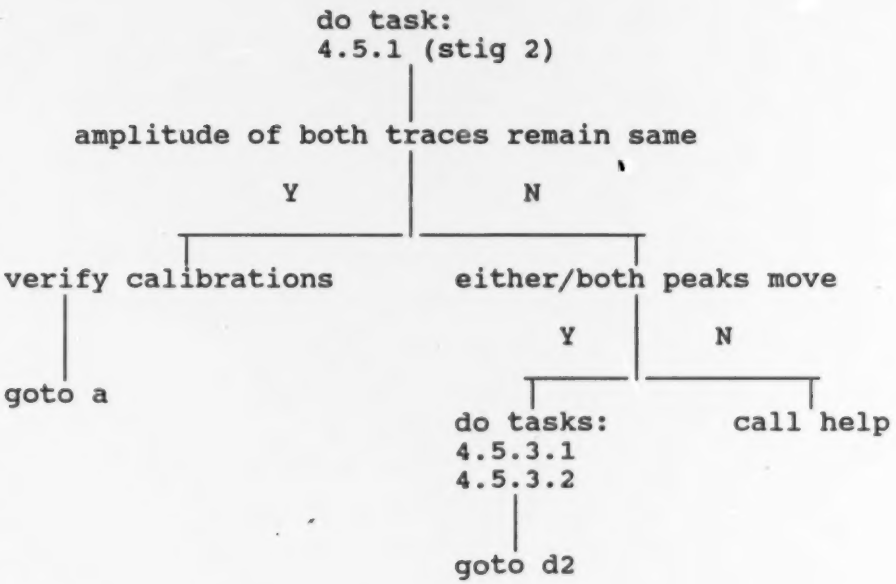
C2.


do tasks
4.4.1 (stig 2)
does the amplitude
stay the same
Y
N
goto d2
both peaks rise
and fall simultaneously
Y
N
do tasks:
4.4.3.1
4.4.3.2
one peak rise while
the other falls
goto c2
Y
N
do tasks
4.4.4.1
4.4.4.2
combination
of
symptoms
goto c2
Y
N
do tasks:
4.4.3.1
4.4.3.2
4.4.4.1
4.4.4.2
call help
goto c2

D1.


do task:
4.5.1 (stig 1)
amplitude of both traces remain same
Y
N
verify calibrations
goto a
either/both peaks move
Y
N
do tasks:
4.5.3.1
4.5.3.2
goto d1
call help

D2.


do task:
4.5.1 (stig 2)
amplitude of both traces remain same
Y
N
verify calibrations
either/both peaks move
goto a
Y
N
do tasks:
4.5.3.1
4.5.3.2
call help
goto d2

APPENDIX I

Expert System Matrix

MATRIX

A.

is * table set at *	* set to correct settings		
N	N	->	do 4.1.1, 4.1.2, 4.2.1 4.2.2, 4.2.3; goto
N	Y	->	do 4.1.1, 4.1.2; goto
Y	N	->	do 4.2.1, 4.2.2, 4.2.3 goto b
Y	Y	->	goto b

B.

stig 1 determined	stig 1 = *	stig 1 = *	either peak unfocused	both peaks unfocused	
Y	Y				-> goto c1
Y	N	Y			-> goto c2
Y	N	N			-> goto b
N	n/a	n/a	Y		-> goto c1
N	n/a	n/a	N	Y	-> goto c2
N	n/a	n/a	N	N	-> call help

C1.

amplitude the same	both peaks rise and fall	one peak rises; other falls	combination of symptoms	
Y				-> goto d1
N	Y			-> do tasks 4.4.3.1, 4.4.3.2; goto c1
N	N	Y		-> do tasks 4.4.4.1, 4.4.4.2, goto c1
N	N	N	Y	-> do tasks 4.4.3.1, 4.4.3.2, 4.4.4.1, 4.4.4.2, goto c1
N	N	N	N	-> call help

C2.

amplitude the same	both peaks rise and fall	one peak rises; other falls	combination of symptoms	
Y				-> goto d2
N	Y			-> do tasks 4.4.3.1, 4.4.3.2; goto c2
N	N	Y		-> do tasks 4.4.4.1, 4.4.4.2, goto c2
N	N	N	Y	-> do tasks 4.4.3.1, 4.4.3.2, 4.4.4.1, 4.4.4.2, goto c2
N	N	N	N	-> call help

D1.

amplitude remain the same	either/both peaks move	
Y		-> verify calibrations b
N	Y	-> do tasks 4.5.3.1 4.5.3.2 goto d1
N	N	-> call help

D2.

amplitude remain the same	either/both peaks move	
Y		-> verify calibrations b
N	Y	-> do tasks 4.5.3.1 4.5.3.2 goto d2
N	N	-> call help

APPENDIX J

Expert System Rule Base

RULE BASE

A.

1. IF * table set to * is NO
   AND * set to correct settings is NO
   THEN do tasks 4.1.1, 4.1.2, 4.2.1, 4.2.2, 4.2,3; goto b.

2. IF * table set to * is NO
   AND * set to correct settings is YES
   THEN do 4.1.1, 4.1.2; goto b.

3. IF * table set to * is YES
   AND * set to correct settings is NO
   THEN do tasks 4.2.1, 4.2.2, 4.2.3; goto b.

4. IF * table set to * is YES
   AND * set to correct settings is YES
   THEN goto b.

B.

1. IF stig 1 is determined is YES
   AND stig 1 = * is YES
   THEN goto c1.

2. IF stig 1 is determined is YES
   AND stig 1 = * is NO
   AND stig 1 = * is YES
   THEN goto c2.

3. IF stig 1 is determined YES
   AND stig 1 = * is NO
   AND stig 1 = * is NO
   THEN determine stig 1; goto b.

4. IF stig 1 is determined is NO
   AND either peak is unfocused is YES
   THEN stig 1 = *; goto c1.

5. IF stig 1 is determined is NO
   AND either peak is unfocused NO
   AND both peaks unfocused is YES
   THEN stig 1 = *; goto c2.

6. IF stig 1 is determined is NO
   AND either peak is unfocused NO
   AND both peaks unfocused is NO
   THEN call help.

C1

1. IF amplitude the same is YES
   THEN goto d1.

2. IF amplitude the same is NO
   AND both peaks fall simultaneously is YES
   THEN do tasks 4.4.3.1, 4.4.3.2; goto c1.

3. IF amplitude the same is NO
   AND both peaks fall simultaneously is NO
   AND one peak rises while other falls is YES
   THEN do tasks 4.4.4.1, 4.4.4.2; goto c1.

4. IF amplitude the same is NO
   AND both peaks fall simultaneously is NO
   AND one peak rises while other falls is NO
   AND combination of symptoms is YES
   THEN do tasks 4.4.3.1, 4.4.3.2, 4.4.4.1, 4.4.4.2; goto c1.

5. IF amplitude the same is NO
   AND both peaks fall simultaneously is NO
   AND one peak rises while other falls is NO
   AND combination of symptoms is NO
   THEN call help.

C2.

1. IF amplitude the same is YES
   THEN goto d2.

2. IF amplitude the same is NO
   AND both peaks fall simultaneously is YES
   THEN do tasks 4.4.3.1, 4.4.3.2; goto c2.

3. IF amplitude the same is NO
   AND both peaks fall simultaneously is NO
   AND one peak rises while other falls is YES
   THEN do tasks 4.4.4.1, 4.4.4.2; goto c2.

4. IF amplitude the same is NO
   AND both peaks fall simultaneously is NO
   AND one peak rises while other falls is NO
   AND combination of symptoms is YES
   THEN do tasks 4.4.3.1, 4.4.3.2, 4.4.4.1, 4.4.4.2; goto c2.

5. IF amplitude the same is NO
   AND both peaks fall simultaneously is NO
   AND one peak rises while other falls is NO
   AND combination of symptoms is NO
   THEN call help.

D1.

1. IF amplitude the same is YES
   THEN verify calibrations; goto b.

2. IF amplitude the same is NO
   AND either/both peaks move is YES
   THEN do tasks 4.5.3.1, 4.5.3.2; goto d1.

3. IF amplitude the same is NO
   AND either/both peaks move is
   THEN call help.

D2.

1. IF amplitude the same is YES
   THEN verify calibrations; goto b.

2. IF amplitude the same is NO
   AND either/both peaks move is YES
   THEN do tasks 4.5.3.1, 4.5.3.2; goto d2.

3. IF amplitude the same is NO
   AND either/both peaks move is NO
   THEN call help.

APPENDIX K

Expert System Screen Design

Screen Number: 10 - Directive

Task #:

Window #: 1

Window Title: Adjust Astigmatism

Size: 2, 5, 21, 70

Color: 11

Text Color: 13

Notes: Window remains up during entire consultation

TEXT

10 20 30 40 50 60 70
0

5

Welcome! The goal of this job aid tool is
to provide guidance in Astigmatism adjustments.

10 Please read the information presented on the
screens carefully, and answer questions with
the appropriate yes or no response.

15 Please press ENTER to begin.

20

25

Screen Name: 20 - Question

Task #: 4.1

Window #: 2

Window Title: Set Up for Astigmatism Adjustment

Size: 4, 9, 3, 61

Color: 0

Text Color: 15

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5
          First, it is necessary to verify the initial
          set up conditions for adjusting astigmatism.
10        Is the * table set at crosswires?
          Type 'y' for yes, 'n' for no.
15
20
25
```

Screen Name: 30 - Question

Task #: 4.1

Window #: 2

Window Title: Set Up for Astigmatism Adjustment

Size: 4, 9, 3, 61

Color: 0

Text Color: 15

Notes:

TEXT

```
10        20        30        40        50        60        70
0

5

10
                  Is the *** set up correctly?
                  Type 'y' for yes, 'n' for no.
15

20

25
```

Screen Name: 40 - Directive

Task #: 4.1

Window #: 3

Window Title: ACTION

Size: 8, 8, 14, 63

Color: 11

Text Color: 141

Notes:

TEXT

```
10        20        30        40        50        60        70
0
5
          Please perform the following set up procedures:

          1.  At MSC terminal type 'XMV X WIRES'
10        2.  At MSC terminal depress ENTER.
          3.  On the *** set *** switch to ON.
          4.  On the *** set *** switch to ON ELEC.
          5.  On the *** set *** switch to TRANSMISSION.

15        Press ENTER to continue with procedure.

20

25
```

Screen Name: 50 - Directive

Task #: 4.1

Window #: 3

Window Title: Action

Size: 8, 8, 14, 63

Color: 11

Text Color: 141

Notes:

TEXT

```
10        20        30        40        50        60        70
0
5
10
          Please perform the following set up procedures:

          1.  At MSC terminal type 'XMV X WIRES'
15        2.  At MSC terminal depress ENTER.

20        Press ENTER to continue with procedure.

25
```

Screen Name: 60 - Directive

Task #: 4.1

Window #: 3

Window Title: Action

Size: 8, 8, 14, 63

Color: 11

Text Color: 141

Notes:

TEXT

```
10        20        30        40        50        60        70
0
5
          Please perform the following set up procedures:
10        1.  On the *** set *** switch to ON.
          2.  On the *** set *** switch to ON ELEC.
          3.  On the *** set *** switch to TRANSMISSION.
15        Press ENTER to continue with procedure.
20
25
```

Screen Name: 70 - Questions

Task #: 4.2

Window #: 5

Window Title: Determine if Stig 1 is on or off axis

Size: 4, 9, 3, 61

Color: 0

Text Color: 15

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0

5

              Based on whether the column is rotated,
              *** may be on axis, or off axis.

10            At this time, do you know if *** is
              on axis, or off axis?

              Please type 'y' for yes, 'n' for no.

15

20

25
```

Screen Name: 80 - Directive

Task #: 4.2

Window #: 4

Window Title: ACTION

Size: 8, 8, 14, 63

Color: 11

Text Color: 141

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5

          Please perform the following procedures to
          determine if *** is on axis or off axis:

10        1.  Misadjust *** on the ***.
          2.  While monitoring the ***, refocus
              the beam by turning the ***
              CW or CCW.

15
          Please press ENTER to continue.

20

25
```

Screen Name: 90 - Question

Task #: 4.2

Window #: 5

Window Title: Determine if Stig 1 is on or off axis

Size: 4, 9, 3, 61

Color: 0

Text Color: 15

Notes: Clearwindow

TEXT

10 20 30 40 50 60 70
0

5

10

Is the amplitude of either peak focused?

Please type 'y' for yes, 'n' for no.

15

20

25

Screen Name: 100 - Question

Task #: 4.2

Window #: 5

Window Title: Determine if Stig 1 is on or off axis

Size: 4, 9, 3, 61

Color: 0

Text Color: 15

Notes:

TEXT

10 20 30 40 50 60 70
0

5

10

Is the amplitude of both peaks focused?

Please type 'y' for yes, 'n' for no.

15

20

25

Screen Name: 110 - Question

Task #: 4.2

Window #: 5

Window Title: Determine if Stig 1 is on or off axis

Size: 4, 9, 3, 61

Color: 0

Text Color: 15

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0

5

                  Is *** on axis?
10
                  Please type 'y' for yes, 'n', for no.

15

20

25
```

Screen Name: 120 - Question

Task #: 4.2

Window #: 5

Window Title: Determine if Stig 1 is on or off axis

Size: 8, 7, 14, 64

Color: 14

Text Color: 0

Notes:

TEXT

```
10        20        30        40        50        60        70
0
5
                    Is *** off axis?
10
                    Please type 'y' for yes, 'n', for no.
15
20
25
```

Screen Name: 130 - Directive

Task #: 4.3

Window #: 6

Window Title: Determine *** Adjustments

Size: 4, 9, 3, 61

Color: 0

Text Color: 15

Notes:

TEXT

```
10        20        30        40        50        60        70
0
5
          Perform the following procedures to determine
          if *** adjustments are necessary:

          While monitoring the ***, turn the ***
10        on the *** CW or CCW so the *** varies.

          Please press ENTER to continue.
15
20
25
```

Screen Name: 140 - Question

Task #: 4.3

Window #: 6

Window Title: Determine *** Adjustments

Size: 8, 7, 14, 64

Color: 0

Text Color: 14

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5
              Does the amplitude of both traces remain
              the same?
10
              Press 'y' for yes or 'n' for no.
15
20
25
```

Screen Name: 150 - Question

Task #: 4.3

Window #: 6

Window Title: Determine *** Adjustments

Size: 8, 7, 14, 64

Color: 0

Text Color: 14

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5
              Does the amplitude of both traces rise
              and fall simultaneously?
10
              Press 'y' for yes or 'n' for no.
15
20
25
```

Screen Name: 160 - Question

Task #: 4.3

Window #: 6

Window Title: Determine *** Adjustments

Size: 8, 7, 14, 64

Color: 0

Text Color: 14

Notes: Clearwindow

TEXT

10 20 30 40 50 60 70
0

5

Does the amplitude of one trace rise while the other falls?

10

Press 'y' for yes or 'n' for no.

15

20

25

Screen Name: 170 - Question

Task #: 4.3

Window #: 6

Window Title: Determine *** Adjustments

Size: 8, 7, 14, 64

Color: 0

Text Color: 14

Notes: Clearwindow

TEXT

10 20 30 40 50 60 70
0

5

Is there a combination of the following waveform symptoms:

10 A) Both traces rise and fall simultaneously.
B) One peak rise while the other peak falls.

Press 'y' for yes or 'n' for no.

15

20

25

Screen Name: 180 - Directive

Task #: 4.3

Window #: 4

Window Title: Action

Size: 8, 8, 14, 63

Color: 11

Text Color: 141

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5
          The following ** adjustments are needed:

          1.  Adjust *** on the *** until peaks are the same.
10        2.  Realign the 3rd aperture.
          3.  Verify adjustment.

          Press ENTER to continue.
15
20
25
```

Screen Name: 190 - Directive

Task #: 4.3

Window #: 4

Window Title: Action

Size: 8, 8, 14, 63

Color: 11

Text Color: 141

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5
          The following ** adjustments are needed:

          1.  Adjust Condenser *** on the *** until peaks
10            are the same.
          2.  Realign the 3rd aperture.
          3.  Verify adjustment.

          Press ENTER to continue.
15
20
25
```

Screen Name: 200 - Directive

Task #: 4.3

Window #: 4

Window Title: Action

Size: 8, 8, 14, 63

Color: 11

Text Color: 141

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5

          The following ** adjustments are needed:

          1.  Adjust Condenser *** on the *** until the
10            peaks are the same.
          2.  Adjust *** on the *** until peaks are the same.
          3.  Realign the 3rd aperture.
          4.  Verify adjustment.

          Press ENTER to continue.

15

20

25
```

Screen Name: 210 - Directive

Task #: 4.3

Window #: 4

Window Title: Action

Size: 8, 8, 14, 63

Color: 11

Text Color: 141

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0

5

                  No adjustments are needed.
10

                  Press ENTER to continue.
15

20

25
```

Screen Name: 220 - Directive

Task #: 4.4

Window #: 8

Window Title: Determine *** Adjustments

Size: 4, 9, 3, 61

Color: 11

Text Color: 141

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0

5

10        While monitoring the ***, turn the *** on the
          *** CW or CCW until the ** varies.

          Press ENTER to continue.

15

20

25
```

Screen Name: 230 - Question

Task #: 4.3

Window #: 8

Window Title: Determine *** Adjustments

Size: 4, 9, 3, 61

Color: 1

Text Color: 14

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5
              Does the amplitude of both traces remain
              the same?
10
              Press 'y' for yes or 'n' for no.
15
20
25
```

Screen Name: 240 - Question

Task #: 4.3

Window #: 8

Window Title: Determine *** Adjustments

Size: 4, 9, 3, 61

Color: 11

Text Color: 14

Notes:

TEXT

10 20 30 40 50 60 70
0

5

Does the amplitude of both peaks move up?

10

Press 'y' for yes or 'n' for no.

15

20

25

Screen Name: 250 - Directive

Task #: 4.3

Window #: 4

Window Title: Action

Size: 8, 7, 14, 64

Color: 11

Text Color: 141

Notes:

TEXT

```
10        20        30        40        50        60        70
0
5
          The following Condenser *** adjustments are
          necessary:
10        1.  While monitoring the ***, adjust Condenser ***
              until the waveforms are flat.
          2.  Realign the 3rd aperture.
          3.  Verify adjustments.
15
          Press ENTER to continue.
20
25
```

Screen Name: 260 - Directive

Task #: 4.3

Window #: 4

Window Title: Action

Size: 8, 7, 14, 64

Color: 11

Text Color: 141

Notes:

TEXT

```
10        20        30        40        50        60        70
0
5
          No Condenser *** adjustments are necessary
10
          Press ENTER to continue.
15
20
25
```

Screen Name: 270 - Question

Task #:

Window #: 7

Window Title: Continue Consultation

Size: 8, 8, 14, 63

Color: 14

Text Color: 12

Notes: Clearwindow

TEXT

```
10        20        30        40        50        60        70
0
5
10        Would you like another consultation?
          Type 'y' for yes, or 'n' for no.
15
20
25
```

Screen Name: 280 - Question

Task #:

Window #: 7

Window Title: Thank You

Size: 8, 8, 14, 63

Color: 14

Text Color: 12

Notes:

TEXT

```
10        20        30        40        50        60        70
0

5

10      Thank you for participating in the Astigmatism
        Expert System.

15

20

25
```

APPENDIX L

Example of IWPS Lesson File Code

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3 Event Detail for Presentation EBL        Event 6.0          43 of 185
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
```

Time

0.0 -

GRAPHIC 60A — Wipe = Pull Down — Time = 0.3
Colors: Trans. = BLACK — Border = BLA
ERROR: GRAPH NOT FOUND

TOUCH TC105

Tch #	Rows	Cols	Branch Feedback
1	4, 7	2,10	6.1 GOOD BEEP
2	7,10	2,10	6.2 GOOD BEEP
3	10,13	2,10	6.3 GOOD BEEP
4	13,16	2,10	6.4 GOOD BEEP
5	16,19	2,10	6.5 GOOD BEEP
6	19,22	2,10	6.6 GOOD BEEP
7	22,25	64,80	+1 GOOD BEEP

SET INDICATORS SW10 to NNNNx.xxxxx.xxxxx.x

0.0 -

GRAPHIC 60B — Wipe = Pull Up — Time = 0.3
Colors: Trans. = BLACK — Border = BLA
ERROR: GRAPH NOT FOUND

TOUCH TC106

Tch #	Rows	Cols	Branch Feedback
1	6, 9	2,10	6.7 GOOD BEEP
2	9,12	2,10	6.8 GOOD BEEP
3	12,15	2,10	6.9 GOOD BEEP
4	15,18	2,10	6.10 GOOD BEEP
5	18,21	2,10	6.11 GOOD BEEP
6	22,25	2,18	-1 GOOD BEEP
7	22,25	20,36	MAINMENU

```
    SET INDICATORS SW10      to NNNNx.xxxxx.xxxxx.x

0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

    BRANCH TO NEXT EVENT 6.1
```

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3 Event Detail for Presentation EBL        Event 6.1          44 of 185
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Time

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC 61A                Wipe = Pull Down                Time =  0.3
                                Colors: Trans. = BLACK          Border = BLA
                                ERROR: GRAPH NOT FOUND

     TOUCH TC107          Tch  Rows    Cols   Branch
                           #                  Feedback
                           1    3, 7    2,10  6.1.1
                                              GOOD BEEP
                           2    7,11    2,10  6.1.2
                                              GOOD BEEP
                           3   11,15    2,10  6.1.3
                                              GOOD BEEP
                           4   15,19    2,10  6.1.4A
                                              GOOD BEEP
                           5   19,23    2,10  6.1.5
                                              GOOD BEEP
                           6   22,25   66,80  +1
                                              GOOD BEEP

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC 61B                Wipe = Pull Up                  Time =  0.3
                                Colors: Trans. = BLACK          Border = BLA
                                ERROR: GRAPH NOT FOUND

     TOUCH TC108          Tch  Rows    Cols   Branch
                           #                  Feedback
                           1    4, 8    2,10  CALL IPI EBLA
                                              GOOD BEEP
                           2    9,13    2,10  6.1.7
                                              GOOD BEEP
                           3   14,18    2,10  6.1.8
                                              GOOD BEEP
                           4   22,25    2,18  -1
                                              GOOD BEEP
                           5   22,25   50,64  6.0:1
                                              GOOD BEEP
```

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3 Event Detail for Presentation EBL        Event 6.1.1        45 of 185
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Time

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC 611                Wipe = Pull Down                Time =  0.3
                                Colors: Trans. = BLACK          Border = BLA
                                ERROR: GRAPH NOT FOUND

     TOUCH TC109           Tch  Rows    Cols   Branch
                            #                  Feedback
                            1  22,25    2,18   6.1:1
                                               GOOD BEEP
                            2  22,25   34,50   +1
                                               GOOD BEEP

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     CLEAR TOUCH

     BRANCH TO +1

 0.1 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC BACKVID            Wipe = None
                                Colors: Trans. = BLACK          Border = BLA
                                ERROR: GRAPH NOT FOUND

     TOUCH BACK            Tch  Rows    Cols   Branch
                            #                  Feedback
                            1  19,23    2,18   -2
                                               GOOD BEEP

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     BRANCH TO NEXT EVENT 6.1.2
```

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3 Event Detail for Presentation EBL        Event 6.1.2        46 of 185
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Time

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC 612                Wipe = Pull Down                Time =  0.3
                                Colors: Trans. = BLACK          Border = BLA
                                ERROR: GRAPH NOT FOUND

     TOUCH TC111           Tch  Rows    Cols  Branch
                            #                 Feedback
                            1  22,25    2,18  6.1:1
                                              GOOD BEEP
                            2  22,25   34,50  +1
                                              GOOD BEEP

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     CLEAR TOUCH

     BRANCH TO +1

 0.1 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC BACKVID            Wipe = None
                                Colors: Trans. = BLACK          Border = BLA
                                ERROR: GRAPH NOT FOUND

     TOUCH BACK            Tch  Rows    Cols  Branch
                            #                 Feedback
                            1  19,23    2,18  -2
                                              GOOD BEEP

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     BRANCH TO NEXT EVENT 6.1.3
```

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3 Event Detail for Presentation EBL        Event 6.1.3        47 of 185
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Time

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC BACKVID          Wipe = None
                              Colors: Trans. = BLACK        Border = BLA
                              ERROR: GRAPH NOT FOUND

     TOUCH TC113          Tch  Rows    Cols  Branch
                           #                 Feedback
                           1  19,23    2,16  6.1:1
                                              GOOD BEEP


 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     BRANCH TO NEXT EVENT 6.1.4A
```

```
ZDDD
```

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3 Event Detail for Presentation EBL        Event 6.1.4B        49 of 185
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Time

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC 614B                Wipe = None
                                 Colors: Trans. = BLACK          Border = BLA
                                 ERROR: GRAPH NOT FOUND

     LITERAL %V6       at  8,13  Colors: Before = LT RED on BLACK
                                         After  = LT RED on BLACK
                                   "      "

     TOUCH TC115                 Tch  Rows    Cols   Branch
                                  #                  Feedback
                                  1    3, 7    2,10   LOOP 6.1.4.4
                                                      GOOD BEEP
                                  2    9,13    2,10   LOOP 6.1.4.5
                                                      GOOD BEEP
                                  3   16,20    2,10   LOOP 6.1.4.6
                                                      GOOD BEEP
                                  4   22,25   64,80   6.1.4C
                                                      GOOD BEEP

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     LITERAL %V7       at  8,22  Colors: Before = LT RED on BLACK
                                         After  = LT RED on BLACK
                                   "      "

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     INPUT VARIABLE %V10         From KEYBOARD at 14,33.  Length = 3
                                 Colors = LT RED on BLACK
                                 Edit Code = +-2,147,483,647 (No dec. pts)

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     INPUT VARIABLE %V11         From KEYBOARD at 21,33.  Length = 3
                                 Colors = LT RED on BLACK
                                 Edit Code = +-2,147,483,647 (No dec. pts)

 0.1 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     BRANCH TO NEXT EVENT 6.1.4C
```

```
ZDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD
3 Event Detail for Presentation EBL        Event 6.1.4C       50 of 185
@DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDD

Time

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     GRAPHIC 614C              Wipe = None
                               Colors: Trans. = BLACK          Border = BLA
                               ERROR: GRAPH NOT FOUND

     TOUCH TC116          Tch  Rows    Cols  Branch
                           #                 Feedback
                           1    5, 9    2,10  LOOP 6.1.4.7
                                              GOOD BEEP
                           2   22,25    2,18  6.1:1
                                              GOOD BEEP

     INPUT VARIABLE %X         From KEYBOARD at 16,9.  Length = 3
                               Colors = WHITE on BLACK
                               Edit Code = +-2,147,483,647 (No dec. pts)

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     INPUT VARIABLE %Y         From KEYBOARD at 19,9.  Length = 3
                               Colors = WHITE on BLACK
                               Edit Code = +-2,147,483,647 (No dec. pts)

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     SUB  %V8      - %V9      = %X       with 0 dec. pts

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     SUB  %V10     - %V11     = %Y       with 0 dec. pts

 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     LITERAL %X       at 16, 9  Colors: Before = LT RED on BLACK
                                        After  = LT RED on BLACK
                                  "     "


 0.0 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

     LITERAL %Y       at 19, 9  Colors: Before = LT RED on BLACK
                                        After  = LT RED on BLACK
                                  "     "
```

APPENDIX M

Prolog Expert System Lesson Code

```
nowarnings
database
        dbase(symbol,char)

predicates
        ebeam
        set_up(symbol)
        response(char)
        checkc(symbol,char)
        clear_facts
        repeat
        procedure_a
        procedure_b
        procedure_c
        stig_1(symbol)
        stig_1_equals
        lens_supply_stig1(symbol)
        lens_supply_stig2(symbol)
        cond_stig1(symbol)
        cond_stig2(symbol)
        verify_or_end
        verify_lens_supply_stig1
        verify_lens_supply_stig2
        title
        verify_condenser_stig1
        verify_condenser_stig2
        verify_or_exit
        again
        no_adjustment_stig1
        no_adjustment_stig2
goal
        title,
        ebeam.
clauses

title:-
        textmode(25,80),
        makewindow(1,13,11,"Adjust Astigmatism",2,5,21,70),
        clearwindow,nl,nl,nl,nl,
        repeat,
        write(" Welcome! The goal of this job aid tool is "),nl,
        write(" to provide guidance in Astigmatism adjustments."),nl,nl,
        write(" Please read the information presented on the"),nl,
        write(" screens carefully, and answer questions with"),nl,
        write(" the appropriate yes or no response."),nl,nl,nl,
        write(" Please press ENTER to begin."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,!,
        clearwindow.

ebeam :-
        clear_facts,
        makewindow(2,0,15,"Set Up for Astigmatism Adjustment",4,9,3,61),
```

```
        makewindow(3,14,0,"",8,7,14,60),
        set_up(_),!,
        makewindow(5,0,15,"Determine if Stig is on or off axis",4,9,3,61
        stig_1(_),!.

clear_facts :-
        retract(dbase(_,_)),fail,!.

clear_facts :-
        nl.

verify_or_exit:-
        makewindow(8,14,12,"Verify Calibrations",8,8,14,63),
        clearwindow,nl,nl,
        write("Do you with to verify calibrations?"),nl,
        write("Press 'y' for yes or 'n' to exit."),nl,
        readchar(Response),
        write(Response),
        Response='y',
        removewindow,
        ebeam.

verify_or_exit:-
        exit.
again:-
        makewindow(7,14,12,"Continue Consultation",8,8,14,63),
        clearwindow,nl,nl,
        write("Would you like another consulation?"),nl,
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Response),
        write(Response),
        Response='y',
        removewindow,
        ebeam.
again:-
        exit.
repeat.
repeat :-
        repeat.

set_up(a):-
        checkc(x_y,'n'),
        checkc(***,'n'),
        procedure_a.

set_up(b):-
        checkc(x_y,'n'),
        checkc(***,'y'),
        procedure_b.

set_up(c):-
        checkc(x_y,'y'),
        checkc(***,'y').
```

```
set_up(d):-
        checkc(x_y,'y'),
        checkc(***,'n'),
        procedure_c.

checkc(Z,X):-
        dbase(Z,Y),X=Y,!.
checkc(x_y,X):-
        not(dbase(x_y,_)),
        repeat,
        clearwindow,nl,
        write(" First, it is necessary to verify the initial"),nl,
        write(" set up conditions for adjusting astigmatism."),nl,nl,
        write(" Is the * table set at crosswires?"),nl,nl,
        write(" Type 'y' for yes, 'n' for no.   "),
        readchar(Reply),
        char_int(Reply,Z),
        Z<122,Z>77,!,
        asserta(dbase(x_y,Reply)),
        X=Reply.

checkc(***,X):-!,
        not(dbase(***,_)),
        repeat,
        clearwindow,nl,nl,nl,
        write(" Is the *** set up correctly?"),nl,nl,
        write(" Type 'y' for yes, 'n' for no.    "),
        readchar(Reply),
        char_int(Reply,Z),
        Z<122,Z>77,!,
        asserta(dbase(x_y,Reply)),
        X=Reply.

procedure_a:-
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write(" Please perform the following set up procedures:"),nl,nl,
        write(" 1.  At MSC terminal type 'XMV X WIRES'."),nl,
        write(" 2.  At MSC terminal depress ENTER."),nl,
        write(" 3.  On the *** set *** switch to ON."),nl,
        write(" 4.  On the *** set *** switch to ON ELEC."),nl,
        write(" 5.  On the *** set *** switch to TRANSMISSION."),nl,nl,
        write(" Press ENTER to continue with the procedure."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,!.


procedure_b:-
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("Please perform the following set up procedures:"),nl,nl,
```

```
        write("1.  At MSC terminal type '****."),nl,nl,
        write("2.  At MSC terminal depress ENTER."),nl,nl,nl,nl,
        write("Press ENTER to continue with the procedure."),
        repeat,
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,!.

procedure_c:-
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("Please perform the following set up procedures:"),nl,nl,
        write("1.  On the *** set *** switch to ON."),nl,nl,
        write("2.  On the *** set *** switch to ON ELEC."),nl,nl,
        write("3.  On the *** set *** switch to TRANSMISSION."),nl,nl,nl
        write("Press ENTER to continue with the procedure."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,!.

stig_1(a):-
        clearwindow,
        makewindow(6,14,0,"",8,7,14,64),
        clearwindow,nl,nl,
        write(" Based on whether the column is rotated,"),nl,
        write(" *** may be on axis, or off axis."),nl,nl,
        write(" At this time, do you know if *** is"),nl,
        write(" on axis, or off axis?"),nl,nl,
        write(" Please type 'y' for yes, 'n' for no.    "),
        readchar(Reply),
        write(Reply),nl,
        clearwindow,
        Reply='y',
        stig_1_equals,!.

stig_1(b):-
        makewindow(4,11,141,"ACTION",8,8,14,63),nl,
        repeat,
        clearwindow,nl,
        write(" Please perform the following procedures to"),nl,
        write(" determine if *** is on axis or off axis:"),nl,nl,
        write("1.  Misadjust *** on the ***."),nl,nl,
        write("2.  While monitoring the ***, refocus"),nl,
        write("the beam by turning the ******"),nl,
        write("**** CW or CCW."),nl,nl,
        write(" Please press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,stig_1(e).

stig_1(e):-
        makewindow(6,14,0,"",8,7,14,64),
        clearwindow,nl,nl,nl,
```

```
        write(" Is the amplitude of either peak focused?   "),nl,nl,
        write(" Please type 'y' for yes, 'n' for no.    "),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',
        clearwindow,nl,nl,
        write(" **** is on Axis"),nl,nl,nl,nl,nl,nl,nl,
        write(" Press ENTER to continue with the procedure."),
        repeat,
        readchar(Next),
        char_int(Next,Z),
        Z=13,!,
        removewindow,
        lens_supply_stig1(_).

stig_1(e):-
        clearwindow,nl,nl,nl,
        write(" Is the amplitude of both peaks focused?"),nl,nl,
        write(" Please type 'y' for yes, 'n' for no."),
        readchar(Reply),
        write(Reply),
        Reply='y',
        clearwindow,nl,nl,
        write("**** is off axis"),nl,nl,nl,nl,nl,nl,nl,
        write("Press ENTER to continue with the procedure."),
        readchar(Next),
        char_int(Next,Z),
        Z=13,!,
        removewindow,
        lens_supply_stig2(_).

stig_1(e):-
        makewindow(10,11,140,"CALL HELP",8,8,14,63),nl,
        repeat,
        clearwindow,nl,nl,nl,
        write(" Please call help."),nl,nl,
        write(" Press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,!,
        removewindow,
        again.

stig_1_equals:-
        makewindow(6,14,0,"",8,7,14,64),
        clearwindow,nl,nl,
        write(" Is *** on axis?    "),nl,nl,nl,
        write(" Please type 'y' for yes, 'n' for no.    "),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',
        lens_supply_stig1(_).

stig_1_equals:-
```

```
        clearwindow,nl,nl,
        write(" Is *** off axis?    "),nl,nl,nl,
        write(" Please type 'y' for yes, 'n' for no."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',
        lens_supply_stig2(_).

stig_1_equals:-
        repeat,
        clearwindow,nl,nl,nl,
        write("You need to determine whether *** is"),nl,
        write("on or off axis "),nl,nl,
        write("Press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,!,
        stig_1(b).

response(Reply):-
        readchar(Reply),
        write(Reply),nl.

lens_supply_stig1(a):-
        makewindow(8,0,15,"Determine ****** Adjustments",4,9,3,61),
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("  Perform the following procedures to determine"),nl,
        write("  if ****** adjustments are necessary:"),nl,nl,
        write("  While monitoring the ***, turn the ******"),nl,
        write("  **** on the ****** CW or CCW so the "),nl,
        write("  *** varies."),nl,nl,
        write("  Please press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        removewindow,
        Z=13,lens_supply_stig1(b).

lens_supply_stig1(b):-
        makewindow(6,14,0,"",8,7,14,64),
        clearwindow,nl,nl,nl,
        write("Does the amplitude of both traces remain "),nl,
        write("the same?"),nl,nl,
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',!,
        no_adjustment_stig1.

lens_supply_stig1(b):-
        clearwindow,nl,nl,nl,
        write("Does the amplitude of both traces rise "),nl,
        write("and fall simultaneously?"),nl,nl,
```

```
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',!,
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("The following ****** adjustments are needed:"),nl,nl,
        write("1.  Adjust **** on the ****** until"),nl,
        write("peaks are the same."),nl,
        write("2.  Realign the 3rd aperture."),nl,
        write("3.  Verify adjustments."),nl,nl,
        write("Press ENTER to repeat procedures necessary to verify "),n
        write("adjustments."),
        readchar(Next),
        char_int(Next,Z),
        removewindow,
        Z=13,verify_lens_supply_stig1.

lens_supply_stig1(b):-
        clearwindow,nl,nl,nl,
        write("Does the amplitude of one peak rise while"),nl,
        write("the other peak falls?"),nl,nl,
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',!,
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("The following ****** adjustments are needed:"),nl,nl,
        write("1.  Adjust CONDENSER **** on the ******"),nl,
        write("until peaks are the same."),nl,
        write("2.  Realign the 3rd aperture."),nl,
        write("3.  Verify adjustments."),nl,nl,
        write("Press ENTER to repeat procedures necessary to verify "),n
        write("adjustments."),
        readchar(Next),
        char_int(Next,Z),
        removewindow,
        Z=13,verify_lens_supply_stig1.

lens_supply_stig1(b):-
        clearwindow,nl,
        write("  Is there a combination of the following waveform"),nl,
        write("  symptoms:"),nl,nl,
        write("  A) Both traces rise and fall simulataneously"),nl,
        write("  B) One peak rise while the other peak falls"),nl,nl,
        write("  Press 'y' for yes or 'n' to exit."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',!,
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
```

```
        clearwindow,nl,
        write("The following ****** adjustments are needed:"),nl,nl,
        write("1.  Adjust **** on the ****** until"),nl,
        write("peaks are the same."),nl,
        write("2.  Adjust CONDENSER **** until the peaks"),nl,
        write("are the same."),nl,
        write("3.  Realign the 3rd aperture."),nl,
        write("4.  Verify adjustments."),nl,nl,
        write("Press ENTER to repeat procedures necessary to verify "),n
        write("adjustments."),
        readchar(Next),
        char_int(Next,Z),
        removewindow,
        Z=13,!,verify_lens_supply_stig1.

lens_supply_stig1(b):-
        makewindow(10,11,140,"CALL HELP",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("  Please call help."),!,nl,nl,
        write("  Press ENTER to continue."),
        response(Reply),
        char_int(Reply,Z),
        Z=13,!,
        removewindow,
        again.

verify_lens_supply_stig1:- !,
        lens_supply_stig1(_).

no_adjustment_stig1:-
        clearwindow,nl,nl,nl,
        write("No ****** adjustments are needed."),nl,nl,
        write("Press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,!,
        cond_stig1(_).

lens_supply_stig2(a):-
        makewindow(8,0,15,"Determine ****** Adjustments",4,9,3,61),
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("  Perform the following procedures to determine"),nl,
        write("  if ****** adjustments are necessary:"),nl,nl,
        write("  While monitoring the ***, turn the ******"),nl,
        write("  **** on the ****** CW or CCW so the "),nl,
        write("  *** varies."),nl,nl,
        write("  Please press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        removewindow,
        Z=13,!,lens_supply_stig2(b).
```

```
lens_supply_stig2(b):-
        makewindow(6,14,0,"",8,7,14,64),
        clearwindow,nl,nl,nl,
        write("Does the amplitude of both traces remain "),nl,
        write("the same?"),nl,nl,
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',!,
        no_adjustment_stig2.

lens_supply_stig2(b):-
        clearwindow,nl,nl,nl,
        write("Does the amplitude of both traces rise "),nl,
        write("and fall simultaneously?"),nl,nl,
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',!,
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("The following ****** adjustments are needed:"),nl,nl,
        write("1.  Adjust **** on the ****** until"),nl,
        write("peaks are the same."),nl,
        write("2.  Realign the 3rd aperture."),nl,
        write("3.  Verify adjustments."),nl,nl,
        write("Press ENTER to repeat procedures necessary to verify "),n
        write("adjustments."),
        readchar(Next),
        char_int(Next,Z),
        Z=13,verify_lens_supply_stig2.

lens_supply_stig2(b):-
        clearwindow,nl,nl,nl,
        write("Does the amplitude of one peak rise while"),nl,
        write("the other peak falls?"),nl,nl,
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',!,
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("The following ****** adjustments are needed:"),nl,nl,
        write("1.  Adjust ****** on the ******"),nl,
        write("until peaks are the same."),nl,
        write("2.  Realign the 3rd aperture."),nl,
        write("3.  Verify adjustments."),nl,nl,
        write("Press ENTER to repeat procedures necessary to verify "),n
        write("adjustments."),
        readchar(Next),
        char_int(Next,Z),
```

```
        removewindow,
        Z=13,!,verify_lens_supply_stig2.

lens_supply_stig2(b):-
        clearwindow,nl,
        write("  Is there a combination of the following waveform"),nl,
        write("  symptoms:"),nl,nl,
        write("  A) Both traces rise and fall simulataneously"),nl,
        write("  B) One peak rise while the other peak falls"),nl,nl,
        write("  Press 'y' for yes or 'n' to exit."),
        readchar(Reply),
        write(Reply),nl,
        Reply='y',!,
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("The following ****** adjustments are needed:"),nl,nl,
        write("1.  Adjust **** on the ****** until"),nl,
        write("peaks are the same."),nl,
        write("2.  Adjust ****** until the peaks"),nl,
        write("are the same."),nl,
        write("3.  Realign the 3rd aperture."),nl,
        write("4.  Verify adjustments."),nl,nl,
        write("Press ENTER to repeat procedures necessary to verify "),n
        write("adjustments."),
        readchar(Next),
        char_int(Next,Z),
        removewindow,
        Z=13,!,verify_lens_supply_stig2.

lens_supply_stig2(b):-
        makewindow(10,11,140,"CALL HELP",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("  Please call help."),!,nl,nl,
        write("  Press ENTER to continue."),
        response(Reply),
        char_int(Reply,Z),
        Z=13,!,
        removewindow,
        again.

verify_lens_supply_stig2:- !,
        lens_supply_stig2(_).

no_adjustment_stig2:-
        repeat,
        clearwindow,nl,nl,nl,
        write("No further adjustment is necessary."),nl,nl,
        write("Press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,!,
        cond_stig2(_).
```

```
cond_stig1(a):-
        makewindow(8,0,15,"Determine ****** Adjustments",4,9,3,61),
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,nl,
        write("While monitoring the ***, turn **** on the "),nl,
        write("***, CW or CCW until the *** varies."),nl,nl,
        write("Press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        removewindow,
        Z=13,cond_stig1(b).

cond_stig1(b):-
        makewindow(6,14,0,"",8,7,14,64),
        clearwindow,nl,nl,nl,
        write("  Does the amplitude of both traces remain the same?"),nl
        write("  Press 'y' for yes or 'n' to exit."),
        readchar(Response),
        write(Response),
        Response='y',
        repeat,
        clearwindow,nl,nl,nl,
        write("  No Condenser **** adjustments are necessary"),nl,nl,
        write("  Please press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,
        verify_or_end.

cond_stig1(b):-
        clearwindow,nl,nl,nl,
        write("Does the amplitude of one or both peaks move up?"),nl,nl,
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Response),
        write(Response),
        Response='y',
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("The following Condenser **** adjustments are"),nl,
        write("necessary:"),nl,nl,
        write("1.  While monitoring the ***, adjust Condenser ****"),nl,
        write("until the waveforms are flat."),nl,
        write("2.  Realign the 3rd aperture."),nl,
        write("3.  Verify adjustments."),nl,nl,
        write("Press ENTER to repeat procedures necessary to verify "),n
        write("adjustments."),
        response(Reply),
        char_int(Reply,Z),
        Z=13,!,
        removewindow,
        verify_condenser_stig1.
```

```
cond_stig1(b):-
        makewindow(10,11,140,"CALL HELP",8,8,14,63),
        repeat,
        clearwindow,nl,nl,
        write("  Please call help."),!,nl,nl,
        write("  Press ENTER to continue."),
        response(Reply),
        char_int(Reply,Z),
        Z=13,!,
        removewindow,
        again.

verify_or_end:-
        clearwindow,nl,nl,
        write("It is important that you verify all calibrations"),nl,
        write("if you have not done so already."),nl,nl,
        write("Please press ENTER to repeat all procedures "),nl,
        write("necessary to verify all calibrations or any"),nl,
        write("other key to exit."),
        response(Reply),
        char_int(Reply,Z),
        Z=13,!,
        ebeam.
verify_or_end:-
        exit.

verify_condenser_stig1:-
        cond_stig1(a).

cond_stig2(a):-
        makewindow(8,0,15,"Determine ****** Adjustments",4,9,3,61),
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,nl,
        write("While monitoring the ***, turn **** on the "),nl,
        write("***, CW or CCW until the *** varies."),nl,nl,
        write("Press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        removewindow,
        Z=13,cond_stig2(b).

cond_stig2(b):-
        makewindow(6,14,0,"",8,7,14,64),nl,
        clearwindow,nl,nl,nl,
        write("  Does the amplitude of both traces remain the same?"),nl
        write("  Press 'y' for yes or 'n' to exit."),
        readchar(Response),
        write(Response),
        Response='y',
        repeat,
        clearwindow,nl,nl,
        write("  No ****** adjustments are necessary"),nl,nl,
```

```
        write("  Please press ENTER to continue."),
        readchar(Reply),
        char_int(Reply,Z),
        Z=13,
        verify_or_end.

cond_stig2(b):-
        clearwindow,nl,nl,nl,
        write("Does the amplitude of one or both peaks move up?"),nl,nl,
        write("Press 'y' for yes or 'n' to exit."),
        readchar(Response),
        write(Response),
        Response='y',
        makewindow(4,11,141,"ACTION",8,8,14,63),
        repeat,
        clearwindow,nl,
        write("The following ****** adjustments are "),nl,
        write("       necessary:"),nl,nl,
        write("1.  While monitoring the ***, adjust ******"),nl,
        write("until the waveforms are flat."),nl,
        write("2.  Realign the 3rd aperture."),nl,
        write("3.  Verify adjustments."),nl,nl,
        write("Press ENTER to repeat procedures necessary to verify "),n
        write("adjustments."),
        response(Reply),
        char_int(Reply,Z),
        Z=13,!,
        removewindow,
        verify_condenser_stig2.

cond_stig2(b):-
        makewindow(10,11,140,"CALL HELP",8,8,14,63),
        repeat,
        clearwindow,nl,nl,
        write("  Please call help."),!,nl,nl,
        write("  Press ENTER to continue."),
        response(Reply),
        char_int(Reply,Z),
        Z=13,!,
        removewindow,
        again.

verify_condenser_stig2:-
        cond_stig2(a).
```

APPENDIX N

Course Aid

IWPS LESSON INITIATION AID

The following is a description of how to begin EB-L training. This description includes the steps needed to initiate the Infowindows system, the training options available, and important characteristics of the lessons.

In addition, a block diagram of the IWPS hardware configuration is provided. This may be of some assistance if the system must be broken down and reconfigured or a problem occurs when the system is turned on. This diagram will allow you to verify that all connections are correct and secure. Finally, directions for filling out the Discrepancy Reports and Reaction Surveys are presented.

It is crucial that these directions are read and followed carefully. It is especially important that you exit the job aid and training module by pressing ALT-F10 keys simultaneously. Any other method used in exiting will cause serious damage to the lesson files.

I DIRECTIONS FOR OPERATION

1. Turn Power ON (and OFF) to the equipment in the following order:

    1. Videodisc Player
    2. Computer
    3. Display Monitor

    The Speech Synthesizer will say "O.K." and the Hardware and Software will be automatically initialized.

2. Choose one of the following Menu Options:

    1. Expert System
    2. Job Aid
    3. Training Module

II EXPERT SYSTEM OPTION

1. After the Expert System option is chosen, you will be prompted to answer questions with a yes or no response, according to conditions displayed by the system.

2. When an appropriate solution is reached, "Engineering Action" procedures will display required diagnostic action.

3. After an appropriate solution is reached you will be asked to choose one of the following options:

    1. Continue with consultation.
    2. Exit the system and return to DOS menu.

III JOB AID OPTION

1. Touch screen at prompt to initialize videodisc player.
    - Screen will display an animated movie "clapboard" that says "Interpreter".
    - The videodisc player will "spin up" and you will hear the drawer open and close.

2. When the system is ready, a graphic screen will display "EL-3". Touch this screen to begin a series of animations. It will stop at MAIN MENU.

    A. Gray boxes are touch sensitive. To select a procedure to perform, touch the box next to the step. Touch the box corresponding to the procedure.
    B. Directions will appear at the bottom of the screen to assist in getting from one screen to another.
    C. When the help box is touched in the upper left-hand corner, a menu will appear. Touch the component you would like to see the location of.

3. To exit, touch the EXIT box on the lower right corner of the main menu screen. This will return you to the DOS menu.

IV TRAINING MODULE OPTION

1. Touch screen at prompt to initialize videodisc player.
   - Screen will display an animated movie "clapboard" that says "Interpreter".
   - The videodisc player will "spin up" and you will hear the drawer open and close.

2. When the system is ready, a series of animations will be presented. The training module will follow.

3. The first part of the training module will be a tutorial concerning beam alignment. Please answer the questions when prompted.
   - NEXT box will advance you to the next screen.
   - BACK box will return to the previous screen.

4. After the tutorial is completed, a simulation will be presented. The purpose of this simulation is to have you perform ABF procedures concerning beam alignment on your own. However, the following prompts are available:
   - NEXT box will provide you with a hint as to the next step.
   - HELP box will tell you the next step.
   - BACK box will return to the previous screen.
   - The ABF keypad will respond to touches. If you know the procedure, it is not necessary to use the prompts at all.

5. At the end of the simulation, you will be asked to choose one of the following options:
   1. NEXT box will return you to the DOS menu.
   2. BACK box will return you to the training module from the beginning.

DISCREPANCY REPORTS

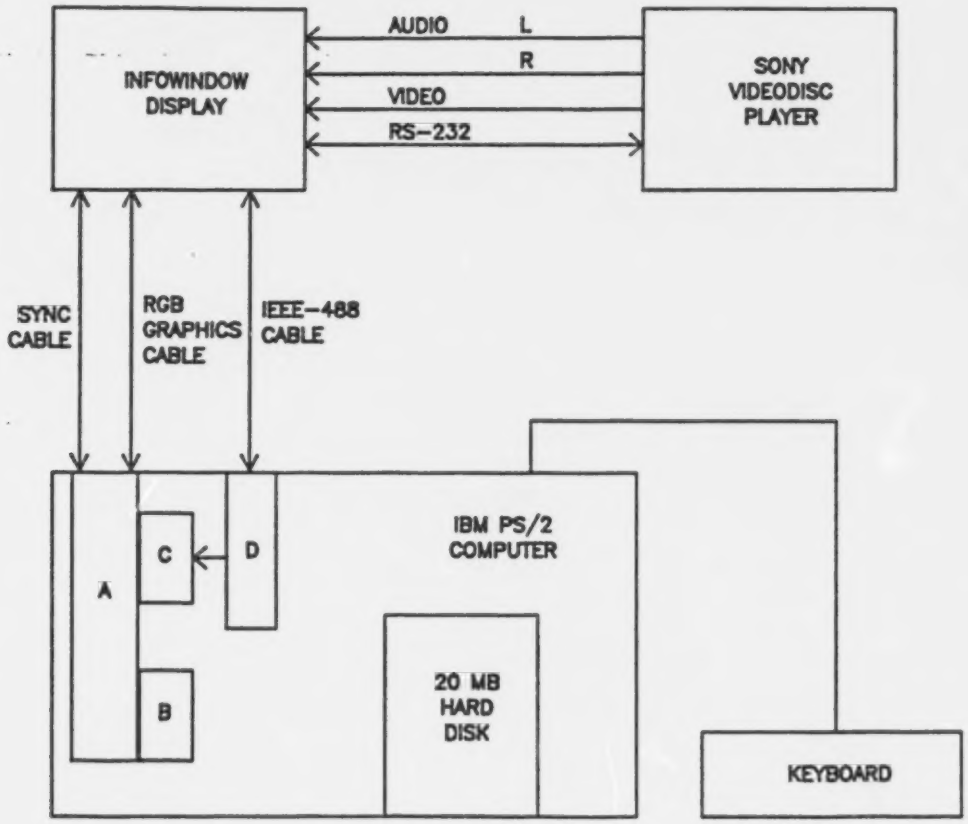
Fill out a discrepancy report if you find:
- A step that tells you the wrong thing to do.
- A step that is missing.
- A step that is confusing
- A typographical error, or wrong terminology.
- A better idea or suggestion of improvements.

To fill out a discrepancy report:
- Fill in boxes 1 - 8, the designers will fill in the rest.
- Reference the number in the upper right-hand corner for box # 4.
- Give the filled out form to your manager.
- The name and phone number section will allow the designers to contact you if necessary.
- Please describe any problems as clearly as possible. Use a separate piece of paper if needed, but please attach it to the form.
- Use flow diagrams, sketches or other documentation wherever possible.

REACTION SURVEYS

Grumman management and the designers of this system would like to get a feel for the users' reaction to the system. It will help them decide how to make improvements to the existing system. It will also help them decide what should and should not be modified. Fill out the survey forms and return them to your manager. Please be honest.

FIGURE 3 INFOWINDOW PRESENTATION SYSTEM BLOCK DIAGRAM



COMPUTER SPECIFICATIONS

640 KB RAM
20 MB HARD DRIVE
A. INFOWINDOW EGA CARD
B. EXPANDED GRAPHICS MEMORY
C. GPIB ADAPTER CARD
D. GPIB INTERFACE CARD

SOFTWARE

1) INFOWINDOW PRESENTATION SYSTEM EDITOR
2) INFOWINDOW PRESENTATION SYSTEM INTERPRETER
3) INFOWINDOW CONTROL PROGRAM
4) IBM DOS 4.0

PERIPHERALS

INFOWINDOW DISPLAY MONITOR WITH TOUCH SCREEN
SONY LDP-1500 VIDEODISC PLAYER

KA-BV21-DSK13

APPENDIX O

Discrepancy Report

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME:	2. DATE:	3. PHONE:	REPORT NO.:
4. STEP NUMBER:	5. STEP DESCRIPTION:		

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☐ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

RECOMMENDED SOLUTION

8.

ANALYSIS

MATERIALS AFFECTED

- ☐ STEP LIST
- ☐ JOB AID
- ☐ TRAINING
- ☐ USER GUIDE
- ☐ VIDEODISC
- ☐ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____ _____

- ☐ STEP LIST _____
- ☐ TRAINING _____
- ☐ EXPERT SYSTEM _____
- ☐ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

RECEIVED BY:	DATE:	COMPLETED BY:	DATE:
ASSIGNED TO:	DATE:	REVIEWED BY:	DATE:

KA-BV25-DSK13

APPENDIX P

Reaction Survey

REACTION SURVEY

Please answer the following questions to the best of your ability. The information you provide will be very helpful to the training designers. You are encouraged to add any comments you wish.

A. First we would appreciate a bit of information concerning your background and experience.

1. Employer Description (Circle One).

Grumman ESD Grumman Tech Services IBM Other

2. What is your job title?

3. How long have you worked on e-beam or related systems?

4. What is your area of specialization?

5. How did you receive your training in your area of specialization.

A. Formal Education

B. Classroom training by employer

C. On-the-job-training

D. Other

B. The next group of questions are about your reaction to the computer-based training module.

1. What was your opinion of the simulation of the ABF keypad?

did not like no opinion liked very much

2. How helpful would simulation of what was occurring in the beam during procedures have been when you were learning your job?

not helpful somewhat helpful very helpful

3. What was your opinion of the computer graphic representations of the beam?

did not like no opinion liked very much

4. How helpful would the graphics and animations have been when you learned your job?

not helpful somewhat helpful very helpful

5. What did you like and dislike about the training demonstration?

_____

_____

_____

_____.

C. The next group of questions are about your reaction to the expert system.

1. Please rate the following areas concerning the expert system, on a scale of 5 (poor) to 1 (good).

A. ease of use	5	4	3	2	1
B. technical accuracy	5	4	3	2	1
C. readability and understanding of procedures	5	4	3	2	1
D. the presentation of procedures	5	4	3	2	1

2. Were the procedures and information logically sequenced?

very well sequenced suitable poorly sequenced

3. Do you feel graphics and waveforms would make the expert system more usable?

yes no maybe

4. Do you feel an expert system would help you better perform diagnostic procedures?

yes no maybe

5. What did you like and dislike about the expert system?

_____

_____

_____

_____.

D. The next group of questions are about your reaction to the computer =-base job aid.

1. Please rate the following areas concerning the expert system, and computer based job aid on a scale of 5 (poor) to 1 (good).

Computer-based Job Aid: (Please circle one).

A. ease of use	5	4	3	2	1
B. quality of graphics	5	4	3	2	1
C. quality of video	5	4	3	2	1
D. technical accuracy	5	4	3	2	1
E. touch screen	5	4	3	2	1
F. readability and understanding of procedures	5	4	3	2	1

2. What was your opinion of the waveforms on the videodisc?

did not like no opinion liked very much

3. How helpful would a job aid (like this one) be to help you recall procedures that you had previously learned?

not helpful somewhat helpful very helpful

4. What did you like and dislike about the computer based job aid?

_____

_____

_____

_____.

E. Please answer the following general questions concerning your opinion of these job performance tools.

1. Do you feel you will be better able to do your job with these job aid tools? (Please circle one).

YES UNCERTAIN NO

2. Would you recommend that other engineers utilized these tools?

YES UNCERTAIN NO

3. What was your overall reaction to this program?

EXCELLENT BETTER THAN EXPECTED SATISFACTORY BELOW AVERAGE

4. How helpful would these job aid tools be to help you recall procedures that you had previously learned?

not helpful somewhat helpful very helpful

5. Based on the following possible results of using these performance tools, please circle the appropriate response.

a. decrease in device downtime	YES	MAYBE	NO
b. standardization of procedures	YES	MAYBE	NO
c. decrease in procedure mistakes	YES	MAYBE	NO
d. documentation of procedures if knowledgeable engineers leave the company	YES	MAYBE	NO

e. decrease in specialization of engineering roles YES MAYBE NO

f. other_____

_____

_____

6. How helpful would an EL-3 simulator be to help you maintain the proficiency of your job skills?

not helpful somewhat helpful very helpful

7. Please use this space for additional comments?

Thank you for your cooperation!

APPENDIX Q

Formative Evaluation Discrepancy Reports

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME: [illegible]	2. DATE: 5/10/90	3. PHONE: 224-[illegible]	REPORT NO.: GR-F-1
4. STEP NUMBER: 5 1	5. STEP DESCRIPTION:		

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☐ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☑ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

MSC Command 'XYM XWIRES' is wrong.

RECOMMENDED SOLUTION

8. Change to 'XYM X WIRES'

ANALYSIS

I think a typographical error; disp list was correct.

MATERIALS AFFECTED

- ☐ STEP LIST
- ☐ USER GUIDE
- ☐ OTHER (SPECIFY) _____
- ☐ JOB AID
- ☐ VIDEODISC
- ☑ EXPERT SYSTEM

☐ STEP LIST _____

☐ EXPERT SYSTEM _____

☑ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

- Error corrected

RECEIVED BY: K. Stewart DATE:

ASSIGNED TO: K. Stewart DATE:

COMPLETED BY: DATE:

REVIEWED BY: DATE:

KA-BV25-DISK13

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME: Mark	2. DATE: 5-4-90	3. PHONE: 224-6445	REPORT NO.: GR-F-2
4. STEP NUMBER: 4.3	5. STEP DESCRIPTION: Lens Supply Adjustment		

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☑ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

Descriptions of waveforms would be easier to understand if video was shown

RECOMMENDED SOLUTION

8.

Video of waveforms similar to job aid

ANALYSIS

Waveform discrepancies presented in steps 4.3 and 4.4 were restated in clearer terms. These changes were verified by B. Clark, SME

MATERIALS AFFECTED

- ☐ STEP LIST
- ☐ USER GUIDE
- ☐ OTHER (SPECIFY) _____
- ☐ JOB AID
- ☐ VIDEODISC
- ☑ EXPERT SYSTEM

- ☐ STEP LIST _____
- ☐ EXPERT SYSTEM _____
- ☐ JOB AID _____
- ☐ OUTLINE _____

ACTION TAKEN:

This comment was presented to management. It was agreed that this is a priority for future training enhancements.

RECEIVED BY: K. Stevenson	DATE: 5/9/90	COMPLETED BY:	DATE:
ASSIGNED TO: K. Stevenson	DATE: 5/10/90	REVIEWED BY:	DATE:

KA-BV23-DISK13

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME: Alex	2. DATE: 5-3-90	3. PHONE: 224-6445	REPORT NO.: GR-F-3
4. STEP NUMBER: 4.2	5. STEP DESCRIPTION: Determine stig 1		

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☒ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

Description of determining whether stig 1 is on or off axis is confusing

RECOMMENDED SOLUTION

8.

more explanation or graphic needed.

ANALYSIS

The reason why stig 1 may be on or off axis was analyzed. This material was added to provide clarity

MATERIALS AFFECTED

- ☐ STEP LIST
- ☐ USER GUIDE
- ☐ OTHER (SPECIFY) _____
- ☐ JOB AID
- ☐ VIDEODISC
- ☒ EXPERT SYSTEM

☐ STEP LIST _____

☐ EXPERT SYSTEM _____

☐ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

(1) Additional explanation
(2) Graphics addition provided to aid in stig 1 alignment

RECEIVED BY: K. Stewart DATE:

ASSIGNED TO: K. Stewart DATE:

COMPLETED BY: DATE:

REVIEWED BY: DATE:

KA-BV25-0SK13

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME:	2. DATE:	3. PHONE:	REPORT NO.:
SHATI	5/3/90	224-6432	GR-F-4

4. STEP NUMBER:	5. STEP DESCRIPTION:
3.3.2.8	3rd literature Alignment

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☐ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☑ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

Change Maximum to Minimum.

RECOMMENDED SOLUTION

8.

Change Maximum to Minimum

ANALYSIS

Change verified by B

MATERIALS AFFECTED

- ☑ STEP LIST
- ☐ USER GUIDE
- ☐ OTHER (SPECIFY) _____
- ☐ TRAINING
- ☐ VIDEODISC
- ☑ JOB AID

- ☐ STEP LIST _____
- ☐ EXPERT SYSTEM _____
- ☐ JOB AID _____
- ☐ OUTLINE _____

ACTION TAKEN:

Maximum Changed to Min.

RECEIVED BY: K. Stiverson DATE:	COMPLETED BY: DATE:
ASSIGNED TO: K. Stiverson DATE:	REVIEWED BY: DATE:

KA-GV25-0SK13

APPENDIX R

Reaction Survey Analysis Results

Survey Results for Electron Beam Lithography Training

May 25, 1990

Simulation Trainer Products

B. The next group of questions are about your reaction to the computer-based training module.

1. What was your opinion of the simulation of the ABF keypad?

FREQUENCY OF RESPONSES

(scale)	Did not Like 5	4	No opinion 3	2	Liked very much 1	Average Rating	Overall Rating
IBM	1			1	9	=1.45	
GRUMMAN TECH.	1		2		13	=1.5	
							=1.48

2. How helpful would the simulation of what was occurring in the beam during procedures have been when you were learning your job?

FREQUENCY OF RESPONSES

(scale)	Not Helpful 5	4	Somewhat Helpful 3	2	Very Helpful 1	Average Rating	Overall Rating
IBM			3		8	=1.54	
GRUMMAN TECH.			5		11	=1.62	
							=1.59

3. What was your opinion of the computer graphic representations of the beam?

FREQUENCY OF RESPONSES

(scale)	Did not Like 5	4	No opinion 3	2	Liked very much 1	Average Rating	Overall Rating
IBM				1	10	=1.09	
GRUMMAN TECH.	1		2		13	=1.5	
							=1.33

4. How helpful would the graphics and animations have been when you learned your job?

FREQUENCY OF RESPONSES

(scale)	Not Helpful 5	4	Somewhat Helpful 3	2	Very Helpful 1	Average Rating	Overall Rating
IBM			4		7	=1.72	
GRUMMAN TECH.			3		12	=1.4	
							=1.53

5. What did you like and dislike about the training demonstration? (+ indicates additional similar comments)

Positive:

- o liked simulation of beam
- o easy to use ++
- o information helpful +
- o repeatability of information
- o good learning tool for novice
- o liked graphic presentation of beam +++
- o touch screen simulated tool itself
- o self-paced

Constructive Criticisms:

- o instructions and wording difficult to understand +++++
- o cannot exit from any screen ++
- o addition information desired (analog meter, DVM readouts) +
- o some graphics inaccurate and misleading ++
- o low fidelity (keypad, DVM, beam movements) +++
- o need more detailed training for those who have no knowledge
- o FRU abbreviations need explanation
- o specific requests for training in specific areas (load/unload)

C. The next group of questions are about your reaction to the expert system.

1. Please rate the following areas concerning the expert system, on a scale of 5 (poor) to 1 (good).

A. ease of use

FREQUENCY OF RESPONSES

(scale) POOR ... GOOD	5	4	3	2	1	Average Rating	Overall Rating
IBM			2	5	4	=1.81	
GRUMMAN TECH.		2	2	1	9	=1.78	
							=1.8

B. technical accuracy

FREQUENCY OF RESPONSES

(scale) POOR ... GOOD	5	4	3	2	1	Average Rating	Overall Rating
IBM	1	3	3	4		=3.09	
GRUMMAN TECH.		3	3	5	3	=2.42	
							=2.72

C. readability and understanding of procedures

FREQUENCY OF RESPONSES

(scale)	POOR 5	4	3	2	GOOD 1	Average Rating	Overall Rating
IBM			6	5		=2.54	
GRUMMAN TECH.		3	1	6	4	=2.21	
							=2.36

D. the presentation of procedures

FREQUENCY OF RESPONSES

(scale)	POOR 5	4	3	2	GOOD 1	Average Rating	Overall Rating
IBM			3	6	1	=2.2	
GRUMMAN TECH.		4	1	3	6	=2.21	
							=2.20

2. Were the procedures and information logically sequenced?

FREQUENCY OF RESPONSES

(scale)	poorly sequenced 5	4	suitable 3	2	very well sequenced 1	Average Rating	Overall Rating
IBM	1		10			=3.18	
GRUMMAN TECH.			12		2	=2.71	
							=2.92

3. Do you feel graphics and waveforms would make the expert system more usable?

FREQUENCY OF RESPONSES

(scale)	no 5	4	maybe 3	2	yes 1	Average Rating	Overall Rating
IBM			2		9	=1.36	
GRUMMAN TECH.			2		12	=1.28	
							=1.32

4. Do you feel an expert system would help you better perform diagnostic procedures?

FREQUENCY OF RESPONSES

(scale)	no 5	4	maybe 3	2	yes 1	Average Rating	Overall Rating
IBM	3		2		6	=2.45	
GRUMMAN TECH.			4		10	=1.57	
							=1.96

5. What did you like and dislike about the expert system?
(+ indicates additional similar comments)

Positive:

- o very helpful for understanding details of procedures
- o helpful tool for tasks forgotten over-time
- o easy to use ++

Constructive Criticisms:

- o needs graphics +++
- o technical accuracy
- o cannot exit from any screen ++
- o would like to ask expert system questions

- o "ACTION" square disruptive
- o needs to be next to Hontas tool
- o information presented specific to one tool ++
- o directions sometimes unclear
- o should include more procedure explanation

D. The next group of questions are about your reaction to the computer-base job aid.

1. Please rate the following areas concerning the expert system, and computer based job aid on a scale of 5 (poor) to 1 (good).

Computer-based Job Aid: (Please circle one).

A. ease of use

FREQUENCY OF RESPONSES

(scale) POOR				GOOD		
	5	4	3	2	1	Average Rating / Overall Rating
IBM			2	5	4	=1.81
GRUMMAN TECH.	2		1	2	10	=1.86
						=1.84

B. quality of graphics

FREQUENCY OF RESPONSES

(scale) POOR				GOOD		
	5	4	3	2	1	Average Rating / Overall Rating
IBM		1	2	4	4	=2.0
GRUMMAN TECH.	2	2	1	3	7	=2.26
						=2.15

C. quality of video

FREQUENCY OF RESPONSES

(scale)	POOR 5	4	3	2	GOOD 1	Average Rating	Overall Rating
IBM			3	4	4	=1.90	
GRUMMAN TECH.	2	2		4	7	=2.2	
							=2.07

D. technical accuracy

FREQUENCY OF RESPONSES

(scale)	POOR 5	4	3	2	GOOD 1	Average Rating	Overall Rating
IBM	1	4	2	3	1	=3.09	
GRUMMAN TECH.	1	1	5	4	3	=2.5	
							=2.76

E. touch screen

FREQUENCY OF RESPONSES

(scale)	POOR 5	4	3	2	GOOD 1	Average Rating	Overall Rating
IBM	1			6	4	=1.90	
GRUMMAN TECH.	2	1		4	8	=2.0	
							=1.96

F. readability and understanding of procedures

FREQUENCY OF RESPONSES

(scale)	POOR 5	4	3	2	GOOD 1	Average Rating	Overall Rating
IBM			3	7	1	=2.18	
GRUMMAN TECH.	2	1	2	5	5	=2.33	
							=2.26

2. What was your opinion of the waveforms on the videodisc?

FREQUENCY OF RESPONSES

(scale)	Did not Like 5	4	No opinion 3	2	Liked very much 1	Average Rating	Overall Rating
IBM	1				10	=1.36	
GRUMMAN TECH.	1		4		10	=1.8	
							=1.61

3. How helpful would a job aid (like this one) be to help you recall procedures that you had previously learned?

FREQUENCY OF RESPONSES

(scale)	Not Helpful 5	4	Somewhat Helpful 3	2	Very Helpful 1	Average Rating	Overall Rating
IBM			4		7	=1.72	
GRUMMAN TECH.			5		10	=1.66	
							=1.69

4. What did you like and dislike about the computer based job aid? (+ indicates additional similar comments)

Positive:

- o easy to use ++
- o information very helpful
- o liked detailed illustrations of crucial information
- o easy to access information that may be forgotten over-time
- o liked touch screen interaction

Constructive Criticisms:

- o touch screen sometimes beeped 2 times; confusing
- o no way to easily exit a chosen procedure +
- o some procedures based on waveforms had identical answers
- o needs diagnostic section
- o technical accuracy
- o graphics jittery
- o description of procedures

E. Please answer the following general questions concerning your opinion of these job performance tools.

1. Do you feel you will be better able to do your job with these job aid tools? (Please circle one).

FREQUENCY OF RESPONSES

(scale)	no 5	4	uncertain 3	2	yes 1	Average Rating	Overall Rating
IBM	2		4		5	=2.45	
GRUMMAN			2		13	=1.26	
							=1.76

2. Would you recommend that other engineers utilized these tools?

FREQUENCY OF RESPONSES

(scale)	no 5	4	uncertain 3	2	yes 1	Average Rating	Overall Rating
IBM	1		1		9	=1.54	
GRUMMAN TECH.					16	=1.0	
							=1.22

3. What was your overall reaction to this program?

FREQUENCY OF RESPONSES

(scale)	BELOW AVERAGE 5	SATISFACTORY 3.6	BETTER THAN EXPECTED 2.3	EXCELLENT 1	Average Rating	Overall Rating
IBM			10	1	=2.18	
GRUMMAN TECH.		2	9	4	=2.12	
						=2.15

4. How helpful would these job aid tools be to help you recall procedures that you had previously learned?

FREQUENCY OF RESPONSES

(scale)	Not Helpful 5	4	Somewhat Helpful 3	2	Very Helpful 1	Average Rating	Overall Rating
IBM			3		8	=1.54	
GRUMMAN TECH.			5		10	=1.66	
							=1.61

5. Based on the following possible results of using these performance tools, please circle the appropriate response.

a. decrease in device downtime

FREQUENCY OF RESPONSES

(scale)	no 5	4	maybe 3	2	yes 1	Average Rating	Overall Rating
IBM	2		7		2	=3.0	
GRUMMAN TECH.	1		12		3	=2.75	
							=2.85

b. standardization of procedures

FREQUENCY OF RESPONSES

(scale)	no 5	4	maybe 3	2	yes 1	Average Rating	Overall Rating
IBM			3		8	=1.54	
GRUMMAN TECH.	1		3		12	=1.62	
							=1.59

c. decrease in procedure mistakes

FREQUENCY OF RESPONSES

(scale)	no 5	4	maybe 3	2	yes 1	Average Rating	Overall Rating
IBM	1		3		7	=1.90	
GRUMMAN TECH.	1		3		12	=1.62	
							=1.74

d. documentation of procedures if knowledgeable engineers leave the company

FREQUENCY OF RESPONSES

(scale)	no 5	4	maybe 3	2	yes 1	Average Rating	Overall Rating
IBM			3		8	=1.54	
GRUMMAN TECH.			5		11	=1.62	
							=1.59

e. decrease in specialization of engineering roles

FREQUENCY OF RESPONSES

(scale)	no 5	4	maybe 3	2	yes 1	Average Rating	Overall Rating
IBM	3		4		4	=2.81	
GRUMMAN TECH.	1		12		3	=2.75	
							=2.77

f. other

- o rapid training of new technicians
- o more useful if attempting unknown procedures

6. How helpful would an EL-3 simulator be to help you maintain the proficiency of your job skills?

FREQUENCY OF RESPONSES

(scale)	Not Helpful 5	4	Somewhat Helpful 3	2	Very Helpful 1	Average Rating	Overall Rating
IBM	1		6		4	=2.45	
GRUMMAN TECH.	2		6		8	=2.25	
							=2.33

7. Please use this space for additional comments? (+ indicates additional similar comments)

- o abbreviations must be explained
- o dynamic nature of tasks may be a problem
- o technical accuracy not exact
- o would like to see more use of graphics and video; can be more helpful in explaining what is going on than actual experience +

- input of practical/precise data would improve understanding
- very professional
- very useful for novice +++
- enjoyed very much
- very easy to use
- would like to exit prematurely and go backwards
- must be implemented next to test stand
- allows free play of procedures, of which there is no opportunity on actual equipment.

APPENDIX S

Data Analysis Specification

This document will serve as a data analysis design, in order to analyze and interpret information collected as a result of EL-3+ training. Because EL-3+ training is the first of its kind, there is little or no information available for proper prediction of how EL-3+ training effects performance (although assumed that training will improve performance, it is not good practice to accept such a speculation without proving some statistical causality). Therefore, what is intended by this analysis is the determination of training-performance relationship indicators, rather than absolute definitions of causality.

It would be a grave mistake to culminate this training effort without determining some tentative generalizations regarding the effect of EL-3+ training on performance and a plan of how to support such generalizations. For this reason, the first step in this data analysis plan will be the determination of a training hypothesis. This will help provide direction and a starting point for training development, as well as a methodology for quantifying data into an operational definition of significant learning.

The EL-3+ hypothesis is compatible with current knowledge concerning training. It has been shown in the past that meaningful, interactive, criterion-referenced training does result in significant learning. This statistical analysis will be applied to the following premise, in the attempt to verify logical consistency of:

IF A=B, AND B=C, THEN A=C

resulting in the following training postulate:

IF meaningful-interactive, criterion-referenced training does increase knowledge of EL-3+ procedures,

AND knowledge of such procedures improves performance,

THEN training will improve performance.

This premise results in the following training hypothesis:

Significant learning about Electron Beam Lithography procedures will occur as a result of criterion-referenced IVD/CBT training.

The correlation of the hypothesis variables (training, performance, knowledge) occurs in two steps. First, an analysis of pre and post test evaluations will be done to determine if there was significant learning. This descriptive analysis will use central tendency and dispersion statistics. Next, a parametric analysis will identify some generalizations concerning the effect of training on the student population based on a student sample. This analysis will use association and inferencing statistics. Finally, some correlation predictions about post test scores and actual performance will occur in order to assess the efficiency and effectiveness of the training. The criteria used to determine satisfactory procedure performance will include decreased device downtime, acceptable wafers, no damage to device, standardized procedures, and maintenance procedure execution time. Before beginning the data collection, it will be necessary to follow these guidelines to ensure the data is unerring and valid (keeping in mind the computer science postulate- garbage in, garbage out). Without these stipulations, the statistical analysis will be rendered meaningless.

First, all data will be reviewed for consistency. All pretest and post test scores will be analyzed for extremes and implausible results or values, which will verify that all scores are accurate and true. Next, all relevant data must be included in the analysis process. If extreme scores are determined valid, they must be included although their effects on analysis outcomes may be undesirable. During all stages of data collection, individual test scores and training results will remain confidential as a result of assigning each student a number that will not indicate any score ownership.

Prior to beginning the statistical analysis, all scores will be documented in the following format:

Student Assigned Number	Pre-test Score	Posttest Score
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

The last assigned student number will signify N, in future applications.

Central Tendency

Next, the statistical analysis will begin by measuring central tendency of both the pre and post test scores. The central tendency measure will provide information about the

grouping of the test scores. In conjunction with the training hypothesis, an increase in the central tendency measurement scores from the pre to post test will be examined. The central tendency techniques to be used will include the mean, median, and mode.

Mean- The mean is the average of all test scores per specified group. The result is calculated by adding all of the pretest values of each individual score and dividing by the total number of scores used. The formula is as follows:

$$\bar{X} = \frac{\Sigma X_i}{N}$$

where:

i = Subscript used to identify EL-3+ student

N = The sample size

$\bar{X}$ = The average value for sample

X = The test result per student

Σ = Summation sign; add items following sign

Median- The median is the measure of central tendency or middle value. There are equal numbers preceding and after the median value.

Mode- The mode is the value or score with the greatest frequency of occurrence.

Because the mean takes into account all the values in the distribution, it is especially sensitive to extreme scores. Therefore, the mean may be somewhat deceitful in that it is drawn in the direction of extreme scores although the extreme score is not a true representative of the sample of scores. For example,

if post test score are 100, 100, 100, 100, 0, 0 then the mean grade of 67 does not provide insight into the true score trend. In this particular case, the mode would be a more discriminating measurement.

Dispersion

Next, measures of score dispersion around the central tendency will be performed. The measure of dispersion is more descriptive than central tendency measures when compared to the pre and post test scores. For example, if the pretest scores are in both the high and low range, and the post test scores are all just above the average, the mean may be the same. However, the dispersion measurement will reflect the differences between the pre and post test scores that central tendency cannot. The three types of dispersion measurements are the range, variance, and standard deviation.

The range is the simplest indication that the two sets of scores differ significantly, by representing both the highest and lowest scores in the distribution. For the purposes of EL-3+ training analysis, the standard deviation dispersion measurement is most crucial. The standard deviation represents a mathematical index of how much the data deviates from the mean value for the group of students. The formula is similar to the measurement of variance, but because variance is measured in squared deviations from the mean, the standard deviation is more applicable due to its original measurements.

The standard deviation is important for two reasons. First, it is used often in future statistical analysis. Second, the

size of the standard deviation will help to indicated the appropriateness of the target population. For example, based on a pretest mean of 72, a standard deviation of 10 will indicate a widely scattered score dispersion. This may mean that some students do not have required prerequisite skills to begin training, while others may be over qualified. The formula is a follows:

$$S = \sqrt{S^2} = \sqrt{\frac{\Sigma(X_i - \bar{X})^2}{N}}$$

Because the standard deviation scores may not be used for comparative purposes (due to its subjectability of the test mean) it will be necessary to convert the pre and post test scores to standard scores or "z" scores for comparison purposes. The "z" score is applicable when dissimilar methods or tests are compared, similar to comparing apples to oranges. In this case, pretest scores will be compared to post test scores (although the pre and post test will be based on the same objectives, the tests will be different, and more that likely so will the means). It is understood in the same terms as standard deviations above or below the mean, although it is calculated as follows:

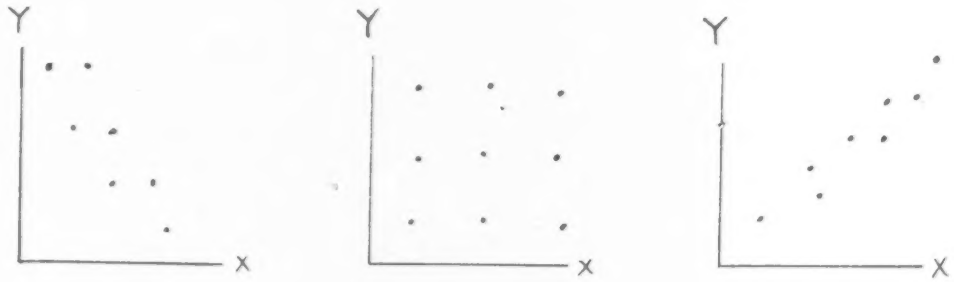
$$Z = \frac{X - \bar{X}}{S}$$

In conjunction with the training hypothesis, what will be examined as a result of z scores is the difference in individual standard scores of the pretest and post test. A positive increase will indicate significant learning has occurred as a result of training.

Association

Measures of association reflect the relationship that exists between two or more groups of data. The two variables to be analyzed for the EL-3+ training will be the pretest and post test scores. Specifically, the degree to which these tests change in relation to one another will be examined. This relationship is also useful in determining whether significant learning has occurred as a result of the training. The degree of the relationship between pretest and post test scores will be measured by a correlation coefficient.

The correlation coefficient varies between -1 and +1. The minus denotes a negative correlation, the plus denotes a positive correlation, and a 0 coefficient denotes no correlation. Examples, of the correlation coefficients are the following:



Negative None Positive

Y axis = Pretest Scores
X axis = Post Test Scores

The range between the absolute positive and negative values are listed below with a general description of the correlation interpretation*.

-	1.0	Perfect negative correlation
-	.8 to - 1.0	Very high degree of negative correlation
-	.6 to - .8	High degree of negative correlation
-	.4 to - .6	Medium degree of negative correlation
-	.2 to - .4	Low degree of negative correlation
+	2 to - .2	Probably no correlation
+	2 to + .4	Low degree of positive correlation
+	4 to + .6	Medium degree of positive correlation
+	6 to + .8	High degree of positive correlation
+	8 to + 1.0	Very high degree of positive correlation
+	1.0	Perfect positive correlations

* These are only approximates. The actual interpretation of specific correlation value depends on the confidence placed on that value.

In conjunction with the training hypothesis, what is desired is a positive correlation (preferably +.6 and higher) between the pre and post test scores, (where the post test equals X axis scores and the pretest equals Y axis scores). Such a correlation would indicate that individual pretest scores increased after training. Therefore, it would be assumed that significant learning occurred.

The formula for calculating correlation is based on the following Pearson r correlation coefficient:

$$r = \frac{n\Sigma X_i Y_i - (\Sigma X_i)(\Sigma Y_i)}{\sqrt{(n(\Sigma X_i^2) - (\Sigma X_i)^2)(n\Sigma Y_i^2 - (\Sigma Y_i)^2)}}$$

Where: X_i = values on X axis
Y_i = values on Y axis

The hypothesis, which is the proposed explanation of the relationship between two or more variables, such as performance and training, for the EL-3+ training is the following:

EL-3+ Training Hypothesis

Significant learning concerning Electron Beam Lithography procedures will occur as a result of criterion-referenced IVD/CBT training.

This hypothesis differs from the problem statements and training goals in that it provides a tentative answer to the problems stated in these items. In order to accept this hypothesis as true, it is necessary to reject the null hypothesis, thus, indirectly accepting (or not rejecting) the training hypothesis.

The null hypothesis, often assumed, is the opposite statement of the hypothesis. In this training situation, it will be stated as the following:

EL-3+ Training Null Hypothesis

Significant learning concerning Electron Beam Lithography procedures will not occur as a result of criterion-referenced IVD/CBT training.

It is the goal of this EL-3+ statistical analysis to test the hypothesis in order to evaluate it as:

a) true- therefore not rejecting the hypothesis

or

b) false- therefore rejecting the hypothesis (and accepting the training hypothesis)

During the evaluation of the above stated null hypothesis, either of two errors could occur, thus corrupting the desired training outcomes. The errors are defined as Type I and Type II errors.

	Ho False (Training does positively effect EL-3+ performance)	Ho True (Training does not positively effect EL-3+ performance)
Reject Ho	Correct Decision	Type I error
Accept Ho	Type II error	Correct Decision

For example, if the the null hypothesis is true and training does not positively effect performance, yet, the hypothesis is rejected, a Type I error has occurred. Similarly, if the hypothesis is false, meaning the training does positively effect the performance, but future training negotiations are terminated, a Type II error has occurred. Both of these errors will negatively effect the desired goals of both IBM, and Grumman.

The process of testing the hypothesis in order to be evaluated, and either rejecting or not rejecting, involves calculating a statistical test value and comparing it with a value from a statistical table. It is most likely that mean values will be utilized in the hypothesis testing procedure.

The formula for the uncorrelated test statistic, t, is as follows:

$$t = \frac{\bar{X} - \bar{Y}}{S_{\bar{X}_c - \bar{Y}_c}}$$

$$\text{where } S_{\bar{X}_c - \bar{Y}_c} = \sqrt{\left(\frac{SS_{X_c} + SS_{Y_c}}{N_1 + N_2 - 2}\right)\left(\frac{1}{N_1} + \frac{1}{N_2}\right)}$$

where: $S_{\bar{X}_c - \bar{Y}_c}$ = Sum of the squares for both tests
SS_{X_c} = Sum of squares for pretest
SS_{Y_c} = Sum of squares for post test
N_1 = sample size for pretest
N_2 = sample size for post test

At this point it is necessary to reiterated that the purpose of this test is to not reject, or reject one of the following hypothesis:

Null hypothesis- the mean of test scores prior to and after training (pre and post test) is the same.

or

Ho: x = u or

Alternative hypothesis- the mean of test scores after training (post test) is greater than prior to training (pretest).

or

Ha: x > u

This analysis is one-sided because it is important to determine if there is a positive effect in EL-3+ performance only (rather than positive and negative effects which would result in a two-sided analysis).

After calculating the t-test outcome, it is necessary to determine the critical value for the t distribution. The two

factors used in the selection criteria are as follows:

1. Degrees of freedom- one less than the number of students. Because there are two sets of scores involved in this analysis, the degrees of freedom will be calculated by adding N + N - 2.
2. Level of significance- the probability value set to test the data for statistical significance. The most common level of significance is .05, meaning there is a 5% chance of making a wrong decision about rejecting the null hypothesis (type I error), which is acceptable for this training application.

Next, it is necessary to compare the test statistic result (t), and the determined critical value in order to verify either of the following conclusions:

If the test statistic value (t) > the critical value then Ho (null hypothesis) is rejected.

or

If the test statistic value (t) < the critical value then the Ho (null hypothesis) is not rejected.

If the training hypothesis is accepted (as a result of indirectly rejecting the null hypothesis), it will be concluded that something other than chance positively effected the post test sample mean scores when compared to the pretest sample mean scores. It would be safe to assume that the training was probably the greatest determinant of this outcome, and did result in significant learning.

APPENDIX T

Summative Evaluation Discrepancy Reports

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME:	2. DATE:	3. PHONE:	REPORT NO.:
Reaction Survey I-4	5/16/90	914-894-0162	I-5-1

4. STEP NUMBER:	5. STEP DESCRIPTION:
3.1.3	Align 1st Aperture

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☑ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

Maximum Second Ap. Current by adjusting 1st alignment

RECOMMENDED SOLUTION

8. This step appears incorrect.

ANALYSIS:

The step is correct, however, the way it was stated may be confusing. The new statement will read: Maximize DVM reading for 2nd Aperture by adjusting 1st alignment.

MATERIALS AFFECTED

- ☑ STEP LIST
- ☑ JOB AID
- ☐ TRAINING
- ☐ USER GUIDE
- ☐ VIDEODISC
- ☐ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____

- ☐ STEP LIST _____
- ☐ TRAINING _____
- ☐ EXPERT SYSTEM _____
- ☐ JOB AID _____
- ☐ OUTLINE _____

ACTION TAKEN:

Step list; job aid were appropriately modified

RECEIVED BY:	DATE:	COMPLETED BY:	DATE:
ASSIGNED TO: K. Stevenson	DATE: 5/24/90	REVIEWED BY:	DATE:

KA-8V25-0SX13

Info. collected from reaction survey. Discrepancy report completed by K. Stevenson.

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME: Reaction Survey GT-13	2. DATE: 5/16/90	3. PHONE: 914-894-0162	REPORT NO.: I-S-2
4. STEP NUMBER: 3.4.2	5. STEP DESCRIPTION: Align 2nd Aperture		

PROBLEM DESCRIPTION

6. CHECK BOX
- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☑ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☐ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:
No rate/speed indications in 2A.

RECOMMENDED SOLUTION

8. This step should be included in 2nd Aperture Alignment procedures.

ANALYSIS

SME's believe this step is correct for Thomas version EL-3+. This will be verified when steps are verified against actual system.

MATERIALS AFFECTED

- ☑ STEP LIST
- ☑ JOB AID
- ☑ TRAINING
- ☐ USER GUIDE
- ☐ VIDEODISC
- ☐ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____

- ☑ STEP LIST _____
- ☑ TRAINING _____
- ☐ EXPERT SYSTEM _____
- ☑ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:
No action taken, until step can be verified against actual system.

RECEIVED BY:	DATE:	COMPLETED BY:	DATE:
ASSIGNED TO: K. Stevenson	DATE: 5/24/90	REVIEWED BY:	DATE:

KA-BV25-DISK13

Info. collected from reaction survey. Discrepancy report completed by K. Stevenson.

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME:	2. DATE:	3. PHONE:	REPORT NO.:
Reaction Survey GT-13	5/16/90	914-894-0162	I-5-3

4. STEP NUMBER:	5. STEP DESCRIPTION:
3.0	CBF command - aligning beam

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☑ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

C and F or
3 and 5

RECOMMENDED SOLUTION

8. Course and Fine selections occur together, whereas, 3 and 5 simple occur together

ANALYSIS

This solution is correct. Step must be verified.

MATERIALS AFFECTED

- ☐ STEP LIST
- ☑ JOB AID
- ☑ TRAINING
- ☐ USER GUIDE
- ☐ VIDEODISC
- ☐ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____

- ☑ STEP LIST _____
- ☑ TRAINING _____
- ☐ EXPERT SYSTEM _____
- ☑ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

Corrections will be implemented. Step must be verified against actual system

RECEIVED BY:	DATE:	COMPLETED BY:	DATE:
ASSIGNED TO: K. Stevenson	DATE: 5/25/90	REVIEWED BY:	DATE:

KA-BV28-DISK13

Info. collected from reaction survey. Discrepancy report completed by K. Stevenson.

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME:	2. DATE:	3. PHONE:	REPORT NO.:
Reaction Survey GT-13	5/16/90	914-894-0162	I-S-4

4. STEP NUMBER:	5. STEP DESCRIPTION:
4.1.1	Software Command- X-Y table

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☑ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☐ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

"XHV WIRES" should be "XHV M WIRES"

RECOMMENDED SOLUTION

8. Content should be re-written and corrected.

ANALYSIS

This command is different for each Hontas version. For the CL-3+, this command is correct.

MATERIALS AFFECTED

- ☑ STEP LIST
- ☑ JOB AID
- ☐ TRAINING
- ☐ USER GUIDE
- ☐ VIDEODISC
- ☑ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____

- ☐ STEP LIST _____
- ☐ TRAINING _____
- ☐ EXPERT SYSTEM _____
- ☐ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

None. Note was made about different Hontas version command.

RECEIVED BY: K. Stevenson DATE: 5/23/90	COMPLETED BY: DATE:
ASSIGNED TO: K. Stevenson DATE: 5/23/90	REVIEWED BY: DATE:

KA-BV25-DISK13

Info. collected from reaction survey. Discrepancy report completed by K. Stevenson.

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME:	2. DATE:	3. PHONE:	REPORT NO.:
Reaction Survey CT-13	5/16/90	914-894-0162	I-S-5

4. STEP NUMBER:	5. STEP DESCRIPTION:
3.8.3	Graphic of ABF LED radiation

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☑ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☐ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

No indication where Target Pot for Servo Led is.

RECOMMENDED SOLUTION

8.

Indication should be presented by highlighted LED.

ANALYSIS

No LED indications were presented by training. This is a future training enhancement.

MATERIALS AFFECTED

- ☑ STEP LIST
- ☑ JOB AID
- ☑ TRAINING
- ☐ USER GUIDE
- ☑ VIDEODISC
- ☐ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____

- ☐ STEP LIST _____
- ☐ TRAINING _____
- ☐ EXPERT SYSTEM _____
- ☐ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

No action taken. Note made for future training enhancement; videodisc modification.

RECEIVED BY: K. Stevenson DATE: 5/23/90	COMPLETED BY: DATE:
ASSIGNED TO: K. Stevenson DATE: 5/23/90	REVIEWED BY: DATE:

KA-BV28-DISK13

Info. collected from reaction survey. Discrepancy report completed by K. Stevenson.

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME:	2. DATE:	3. PHONE:	REPORT NO.:
Reaction Survey GT-12	5/16/90	914-894-0162	I-5-6

4. STEP NUMBER: 4.0 – 4.3

5. STEP DESCRIPTION: Stig 1 on or off axis

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☑ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

I noticed on assignment in procedure, program ads the following comment:
"Based on whether the column is rotated, Stig 1 may be on axis or off axis."
This is confusing.

RECOMMENDED SOLUTION

8.

It would be better to call Stig 1 on axis and Stig 2 off axis for less confusion.

ANALYSIS

Step is correct, new wording is appropriate.

MATERIALS AFFECTED

- ☑ STEP LIST
- ☑ JOB AID
- ☐ TRAINING
- ☐ USER GUIDE
- ☐ VIDEODISC
- ☑ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____

☐ STEP LIST _____

☐ TRAINING _____

☐ EXPERT SYSTEM _____

☐ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

Appropriate changes were made to training.

RECEIVED BY: K. Stevenson DATE: 5/23/90
ASSIGNED TO: K. Stevenson DATE: 5/23/90

COMPLETED BY: DATE:
REVIEWED BY: DATE:

KA-BV25-DISK13

Info. collected from reaction survey. Discrepancy report completed by K. Stevenson.

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME:	2. DATE:	3. PHONE:	REPORT NO.:
		914-894-0162	I-5-7

4. STEP NUMBER:	5. STEP DESCRIPTION:
5.0	Graphic of Beam Column

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☐ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☑ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

GRAFIC showing A PROPERLY ALIGNED should HAVE APERTURES AND CROSSED LABELED

RECOMMENDED SOLUTION

8.

Labels should appear on column graphic.

ANALYSIS

This is an aesthetic modification. When a future disc is developed and pressed, this suggestion will be considered.

MATERIALS AFFECTED

- ☐ STEP LIST
- ☐ JOB AID
- ☑ TRAINING
- ☐ USER GUIDE
- ☑ VIDEODISC
- ☐ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____

- ☐ STEP LIST _____
- ☐ TRAINING _____
- ☐ EXPERT SYSTEM _____
- ☐ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

No action at this time. Note made concerning videodisc modification.

RECEIVED BY:	DATE:	COMPLETED BY:	DATE:
ASSIGNED TO: K. Steveitson	DATE: 5/24/90	REVIEWED BY:	DATE:

KA-BV25-DISK13

DISCREPANCY REPORT

DIRECTIONS:
- FILL IN BOXES 1 – 8
- SUBMIT TO MANAGER

1. NAME: Reaction Survey GT-8	2. DATE: 5/16/90	3. PHONE:	REPORT NO.: I-5-8
4. STEP NUMBER: 4.1.1	5. STEP DESCRIPTION: Select command - X-Y table		

PROBLEM DESCRIPTION

6. CHECK BOX

- ☐ CRITICAL: TEACHES ERRONEOUS CONTENT.
- ☑ SERIOUS: FAILS TO TEACH REQUIRED CONTENT.
- ☐ CONFUSING: CONTENT NOT ORGANIZED/ EXPLAINED CLEARLY.
- ☐ MINOR: TYPOGRAPHIC, ETC.
- ☐ SUGGESTION

7. DESCRIBE PROBLEM:

"XHV X WIRES" could be "XHV H CWON"

RECOMMENDED SOLUTION

8. Content should be re-written and corrected.

ANALYSIS

This command is different for each Hero version. For the GL-B+, this command is correct.

MATERIALS AFFECTED

- ☑ STEP LIST
- ☑ JOB AID
- ☐ TRAINING
- ☐ USER GUIDE
- ☑ VIDEODISC
- ☑ EXPERT SYSTEM
- ☐ OTHER (SPECIFY) _____

- ☐ STEP LIST _____
- ☐ TRAINING _____
- ☐ EXPERT SYSTEM _____
- ☐ JOB AID _____ ☐ OUTLINE _____

ACTION TAKEN:

Okay. Note was made about different Hero's version command.

RECEIVED BY: K. Stevenson DATE:
ASSIGNED TO: K. Stevenson DATE: 5/23/90

COMPLETED BY: DATE:
REVIEWED BY: DATE:

KA-BV25-DISK13

Info. collected from reaction survey. Discrepancy report filled out by K. Stevenson.

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